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(Unclassified Title) E-1473 ANALYSIS OF LEM MISSION INERTIAL UNCERTAINTIES

by
John M. Dahlen
Malcolm W. Johnston
December 1963

INSTRUMENTATION LABORATORY

CAMBRIDGE 39, MASSACHUSETTS

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ANALYSIS OF LEM MISSION INERTIAL UNCERTAINTIES

ABSTRACT

The major sources contributing to LEM position and velocity uncertainties at perilune, hover, and burn-out are individually investigated. The format utilized to trace each component uncertainty through these phases also serves as a common basis upon which the following alternate inertial schemes are compared:

- 1. Gimballed vs gimballess inertial measurement unit,
- 2. Crude vs precision gyros,
- 3. Inertial realignment between injection and perilune vs no realignment.

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TABLE OF CONTENTS

						<u>Pa</u>	ge
I	LIST C	F SYMBO	LS .				7
II	INTRO	DUCTION	, .				9
III	DISCUS	SSION , .	, ,	• •			3
	Orb	ital Naviga	ation	n Unce	rt	ainties 1	3
	LEN	M Inertial	Unc	ertaint	ie	s.,	3
	Illus	strative E	kam	ple .			3
IV	CONCI	LUSIONS .	, ,			,	7
V	REFE	RENCES .			,		9
VI	APPEI	NDICES .	. ,			. , , , ,	7
	Α.	Analysis	Ι	GIMU	-	Precision Gyros - Realignment	7
	В.	Analysis	II	IMU	-	Precision Gyros - Realignment 4	:1
	С.	Analysis	III	GIMU	-	Precision Gyros - No Realignment 4	:3
	D.	Analysis	IV	IMU	-	Precision Gyros - No Realignment	3
	${f E}$.	Analysis	V	GIMU	-	Crude Gyros - Realignment	55
	F.	Analysis	VI	GIMU	-	Crude Gyros - No Realignment	
	G.					nt and Ascent Trajectory	

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I LIST OF SYMBOLS

IMU Gimballed inertial measurement unit

GIMU Gimballess inertial measurement

unit

(U)R, (U)T, (U)H Range, track, altitude uncertainty

 $(U)\dot{R}$, $(U)\dot{T}$, $(U)\dot{H}$ Range rate, track rate, altitude

rate uncertainty

BDX, BDY, BDZ Bias drift about x, y, z axes

ACBX, ACBY, ACBZ Accelerometer bias along the x, y,

z axes

SFEX, SFEY, SFEZ Accelerometer scale factor uncer-

tainty along the x, y, z axes

MLM Misalignment

Inj Injection

Per Perilune

Hover Hover

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ANALYSIS OF LEM MISSION INERTIAL UNCERTAINTIES

II INTRODUCTION

The major sources contributing to position and velocity uncertainties during a LEM mission are investigated.

A format is presented (in the appendix) that traces the effects of each uncertainty source from injection of the LEM into its descent orbit through perilune and hover to burn-out. The format serves three purposes:

- 1. It reveals the important sources of inertial uncertainties and when they occur,
- 2. It indicates the effects of "initial condition" or orbital navigation uncertainties,
- 3. It serves as a common basis for the analysis and comparison of several alternate inertial guidance schemes.

Three comparisons were made:

- 1. Gimballed vs gimballess inertial measurement unit,
- 2. "Crude" vs "precision" gyros,
- 3. Realignment of IMU and GIMU between injection and perilune vs no realignment.

Table I summarizes the results obtained when one assumes that each component uncertainty, though unknown, is constant over the entire mission profile. Table II shows the results if one assumes that each component uncertainty changes in random fashion from one phase to the next within the mission profile. A detailed analysis of each component contribution

for both tables is included in Appendices A-F. Table III indicates qualitatively the effects of guidance uncertainties on fuel requirements. Table IV summarizes the resultant cut-off uncertainties for a normal ascent from the lunar surface.

Figure 1 illustrates the phases of the LEM mission as well as indicating the coordinate systems utilized.

The body of this report will be restricted to a brief discussion of the selected uncertainty sources followed by an illustrative example of the analysis, tracing the effects of a single uncertainty source through all mission phases.

The analyses involve LEM inertial uncertainties and initial condition uncertainties only. No scheme employing external sensing during landing is considered. (External terminal guidance has the principal effect of nulling terminal velocity and altitude errors).

For Tables I and II, an abort from hover was used instead of a normal launch because the abort case appeared to be most critical with respect to subsequent rendezvous maneuver fuel requirements.

The position and velocity uncertainties listed in Tables I and II are "Root-Sum-Square" values. For example, the RSS range uncertainty is the square root of the sum of the variances* in range uncertainty due to each uncertainty source. If the

Variance (X) =
$$(X - \overline{X})^2$$

The standard deviation or "one sigma variation" of X is the square root of the variance. That is:

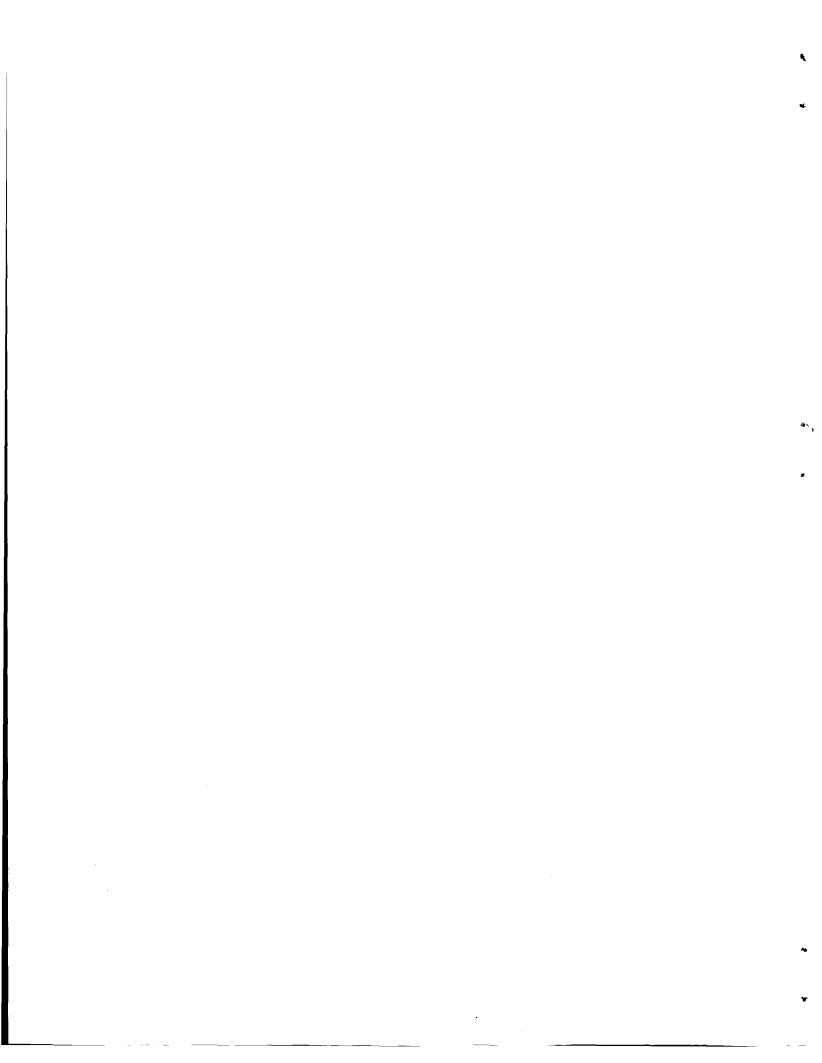
$$\sqrt{\text{Variance}}$$
 (X) = STD. DEV. (X) = σ (X)

^{*} The variance of a random variable, X, is the average value of the square of the difference between X and its average value, \overline{X} . That is:

sources are independent (a valid assumption) the RSS range uncertainty is also the square root of the variance of the total range uncertainty. The results in Tables I and II may therefore safely be called RMS or 1σ uncertainties.

Certain qualifications regarding the analysis should be pointed out. First, regarding accuracy of the GIMUs, two bias drift rates were assumed to correspond to "crude" and "precision" gyros. For "precision" gyros, 10 meru drift was used to see the result that would occur if gyro performance were not degraded in the "strap-down" environment. For "crude" gyros, 66.7 meru (1.0 degree/hour) drift was used to gain feel for the trajectory errors that would result from gyro performance degradation. While the best engineering judgment of the Apollo Staff anticipates a serious performance degradation in the early application of the gyro in the "strap-down" environment, there is no sound technical basis for assuming that such degradation can be treated as a factor of seven increase in bias drift. This treatment is simply the most appropriate method in view of the lack of information and time needed for a more valid performance comparison.

Secondly, as will be seen, gross trajectory errors associated with 1.0 degree/hour gyro drift can be greatly decreased by realignment fifteen minutes before perilune. It should be understood that such a re-alignment, while possible, would rather seriously interfere with an otherwise orderly and comfortable sequence of astronaut activities in preparation for the start of the powered descent. The re-alignment would require re-orientation of the vehicle and about five minutes of time.



III DISCUSSION

This study concerns the uncertainties in position and velocity existing at various phases of the LEM mission as a result of orbital navigation schemes and LEM inertial instrumentation. Reference to a summary sheet of one of the schemes analyzed (Appendices A-F) will clarify the following discussion.

Orbital Navigation Uncertainties

This category consists of those position and velocity uncertainties that exist prior to LEM injection. They represent the sum of all CM system uncertainties up to this point in the mission. The particular numbers used correspond to an M.I.T. orbital navigation scheme - Model I - Std (Reference 1). Their appearance on the summary sheet is desirable in order that LEM inertial uncertainties be kept in perspective. Larger orbital navigation uncertainties would tend to overwhelm the LEM inertial uncertainties thus diminishing the importance of the latter.

LEM - Inertial Uncertainties

The first uncertainty source listed under this category, alignment, means the misalignment of the accelerometer package which results from star tracking uncertainties, angle read-out uncertainties, etc. Gyro bias drift, accelerometer bias, and accelerometer scale factor uncertainty constitute the most important inertial uncertainties for the LEM mission though many more exist. (Reference 2)

Illustrative Example

1

The example chosen to illustrate the use of appendices utilizes a GIMU with "precision" gyros and a realignment



between injection and perilune. In particular, the effect of the constant drift of 10 meru (0.15 degrees/hour) of the y gyro will be traced to burn-out. (Appendix A, analysis I, BDY, page 34)

The left hand column of this analysis sheet divides the mission into separate phases of instrument utilization. In this case four phases are delineated. We consider each phase separately, or independently, so that we can calculate the final uncertainties when the component uncertainty is assumed to vary from one phase to the next.

Within each phase individual uncertainty sources are listed. (It should be remembered that these are, in turn, a result of the single uncertainty source represented by the particular analysis sheet, BDY in this case). The following example may clarify the shorthand notation utilized throughout the analyses: y Per mlm reads, "the misalignment about the y axis at perilune." To the right of each listed source is seen its effects at perilune, hover, and burn-out. Each of these phases is described in more detail below.

1. Drift Between Alignment and Injection

Fifteen minutes of drift occurring between initial alignment and injection causes a misalignment about the y axis at injection of 0.0375° (See Fig. 1). Application of 373 feet/second (essentially radial injection velocity) results in a range rate uncertainty of 0.24 feet/second at injection because of this thrust vector misalignment.

The perilune effects of this injection velocity uncertainty were obtained through free fall error propagation equations. (Reference 3)

The perilune position and velocity uncertainties just obtained are propagated to hover and burn-out by means of a



"GIMU guidance error sub-routine" into which is fed knowledge of the descent and ascent trajectory parameters. The results of this routine (developed by F. Grant - M.I.T. Instrumentation Laboratory) are used to determine all effects occurring during, or being propagated through, any powered phase. (Description of the descent and ascent trajectories used in the error subroutine are included as Appendix G).

2. Drift Between Realignment and Perilune

The misalignment at injection has been wiped out by the realignment performed 15 minutes before perilune.

Fifteen minutes of drift occurring between realignment and perilune causes a misalignment about the y axis at perilune of 0.0375°. The GIMU error sub-routine determines the effects of this misalignment on position and velocity at hover and propagates these uncertainties at hover to burn-out.

In addition, the misalignment at perilune transforms to a like misalignment at hover, the effects of which are propagated to burn-out. (In this case the body and target axes coincide. A more complicated transformation is required if they don't. An x or z misalignment at perilune results in both an x and a z misalignment at hover.

3. Drift During Descent

During the six minutes of powered descent the continuous gyro drift rate causes position and velocity uncertainties at hover which are, in turn, propagated to burn-out.

In addition, a misalignment at hover, due to the integrated effect of gyro drift during descent, must also be propagated to burn-out. (Again, a more complicated computation of integrated drift effects is necessary for the x and z gyros).

4. Drift During Ascent

Finally, the continuous bias drift acting during the ascent



will result in uncertainties at burn-out. Again, these are obtained from the error sub-routine.

There are two different ways of handling the columns of uncertainty figures corresponding to perilune, hover, and burnout appearing on each analysis sheet. Remember that the entire sheet concerns a single instrument uncertainty. It could be argued that the value of the instrument uncertainty is not the same during all phases of instrument utilization, i.e., the drift during the injection is not the same as the drift during powered ascent, etc. Within each phase, however, it has been assumed that each component uncertainty can be assumed constant. If one assumes that the instrument uncertainty shifts randomly from one phase to the next, it is necessary to RSS the position and velocity uncertainties found for each phase.

An alternate approach would be to consider that the uncertainty, though unknown, is constant throughout the mission, in which case we arithmetically add the position and velocity uncertainties found for each phase.

Both procedures are followed on the analysis sheets, the latter technique is represented on Table I, the former on Table II. The actual uncertainties will, most likely, lie somewhere between these two extremes.





IV CONCLUSION

The following remarks primarily concern information appearing in summary form on Table I and II.

Comparisons of analyses I and II or III and IV indicate the effects of a gimballed vs a gimballess inertial measurement unit. Both systems yield essentially the same results at perilune and hover while the gimballess system gives better results at burn-out. This is a result of the fact that the body-mounted gyros and accelerometers are flipped (as the vehicle is reoriented) at hover so that the sense of their uncertainties during ascent tends to cancel the uncertainties built up during descent. This cancellation is much less pronounced if the uncertainties are assumed to be variable (Table II).

The effects of crude (1.0°/hr or 66.7 meru) vs precision (0.15°/hr or 10 meru) gyros are found by comparing analysis I and V or III and VI. Though the gyro bias drifts differ by more than a factor of six, all other effects contributing to the total uncertainty figures remain the same. Therefore, the effects of gyro degradation are somewhat subdued. Nonetheless, reference to Table I indicates how significant such degradation is to hover and burn-out conditions, especially in terms of CEP and burn-out velocity uncertainties.

The effects of realignment vs no realignment between injection and perilune can be seen by comparing analyses I and III, or II and IV, or V and VI. In the first two comparisons, where precision gyros are used, it is seen that the effects primarily involve larger hover uncertainties. If crude gyros are employed and the system is not realigned prior to perilune,

a poor scheme (V) becomes even worse (VI) in position and velocity uncertainties at both hover and burn-out.

The principal differences between Tables I and II concern altitude and altitude rate uncertainties. These are nicely cancelled to a large extent because of the sequence of axes rotations if one can assume constant uncertainties (Table I). The terms are significant because they effect landing altimeter acquisition altitude and abort trajectory lofting. It is, therefore, important to find a realistic method of analysis with respect to these terms. It is also important to point out that increased inertial guidance uncertainties involve increased fuel consumption. Table III attempts to point out the principal accuracy/fuel relationship without attempting to assign numerical values. The results shown on Table IV suggest that a minimum time between alignment and launch is most critical, especially in a system utilizing crude gyros.

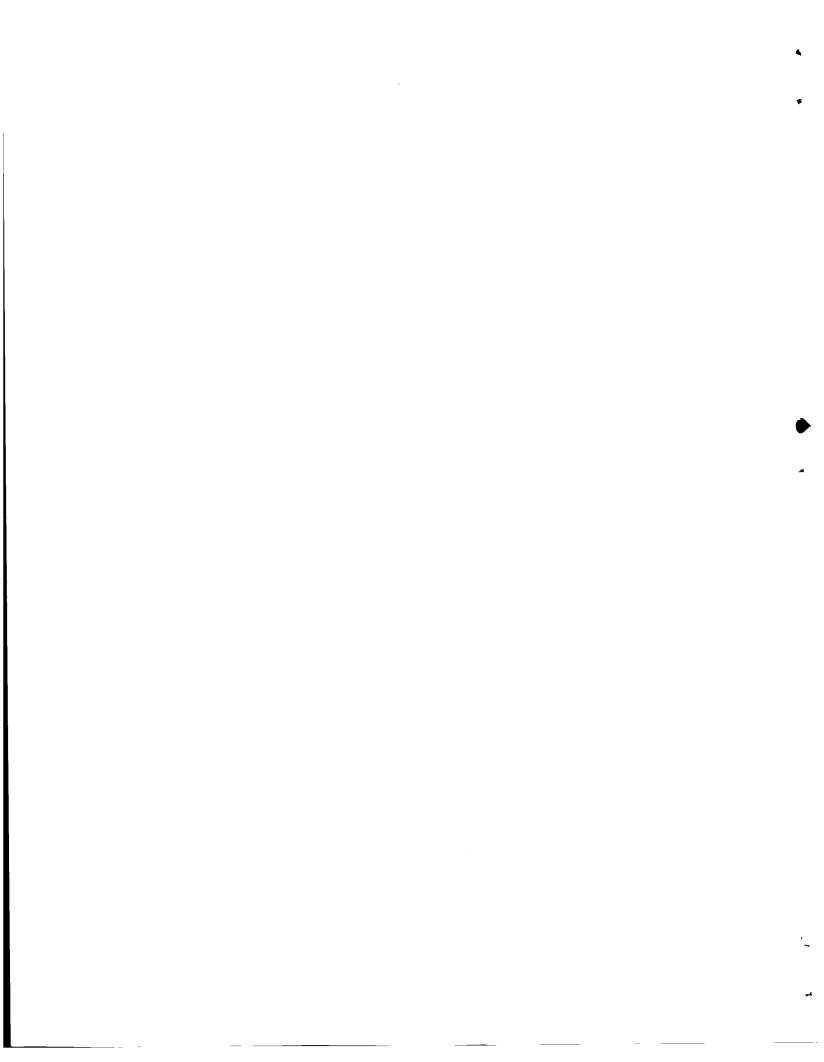
Further discussion of the many ramifications of these results will not be attempted here.

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 Apollo Guidance and Navigation Program, M. I. T.

 Instrumentation Laboratory Report, E 1306, Period from January 11, 1963 to February 11, 1963.
- IMU Error Data For Apollo Trajectories, Frederic
 D. Grant, M. I. T. Instrumentation Laboratory Report, E 1212, September, 1962.
- 3. Summary of Error Propagation in an Inertial System,
 Janusz Sciegienny, M. I. T. Instrumentation Laboratory
 Report, E 1388, August, 1963



COMPANY

TABLE I

LEM INERTIAL UNCERTAINTIES
(Instrument uncertainties constant throughout mission)

		Unce	Uncertainties* at Perilune	* at Per	ilune				Unc	Uncertainties at Hover	s at Hov	èr			Unc	Uncertainties at Burn-out	s at Burn	-out	
ANALYSIS	(U)R	T(U)	H(n)	(U) Å	(U)	(U) મ		(U)R.	T(U)	н(л)	(U)Å	(U)†	(U) મໍ	(U)R	T(U)	н(п)	(U)	r(U)	h (U)
I.) GIMU Precision Gyro: Realignment	1485	703	928	0,61	0.53	1,62		1670	1432	687	2, 43	5,62	4,51	1789	2719	1172	2.03	2.03 4.40	2.82
II.) IMU Precision Gyro, Realignment			Sa	Same			·	1593	1399	732	2.52	5.74	4.86	2070	2671	1734	5, 28	5, 56	5.38
III.) GIMU Precision Gyro; No Realignment			S _B	Same				1762	2395	1332	2.71	2.71 12.29	11.38	1840	4788	3519	3.44	3,44 5,35	2.22
IV.) IMU Precision Gyro; No Realignment			Sa	Same				1592	2379	1407	3.06	12.43	12.31	2203	4708	4005	7.24	7.85	. 98
V.) GIMU Crude Gyro; Realignment	1958	1847	3545	1,69	0.53	4.65		3927	6716	687	4.84	4.64 29.22	23.63	4861	11901	3457	10.02	10.02 10.02	11.86
VI.) GIMU Crude Gyro; No Realignment			S.	Same				5416	14456	7673	9.25	9.25 78.54	73.51	5647	28859 22385	22385	21.04 22.59	22.59	2.33

*All 10 uncertainties

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TABLE II.

LEM INERTIAL UNCERTAINTIES

(Instrument uncertainties vary randomly from one phase to the next)

		Unce	Uncertainties* at Perilunc	at Peril	nne			Unk	ertaintie	Uncertainties at Hover	L.			Unc	crtainties	Uncertainties at Burn -out	-out	-
ANALYSIS	(U)R (U)T	1	н(п)	(U)	(U)T	(U)ii	(U)R	(U)T	н(а)	(U)Å	(U)Ť	(U)	(U)R	T(1)	н(л)	(U)Å	Ť(U)	(U)
I.) GIMU Precision Gyro: Realignment	1485	703	928	0.61	0.53	1,62	1722	1088	1538	2.47	5, 25	5.62	2215	2108	2938	3.45	3, 41	4.89
III.) GIMUse Precision Gyro: No Realignment	1485	703	928	0.61	0.53	1,62	1769	3021	2116	2.72 11.72		11,83	2231	4225	4812	7. 22	4, 40	5.39
V.) GIMU Crude Gyro. Realignment	1958	1847	3545	1.69	0.53	4,65	3215	4469	6483	3,98 25.54	25.54	26.68	4769	8950	8950 12367	7.04	9,72	14.23
VI.) GIMU Crude Gyro, No Realignment	1958	1847	3545	1.69	0.53	4.65	3926	11913	12599	8.07 74.50	. 1	75.55	4916	1	25786 29634	17.17 20.91	i	22.54

*All 10 uncertainties
**No IMU data available
for analyses II. and IV.

CONTRACTION

TABLE III

Effects of Guidance Uncertainties

on Fuel Requirements

Guidance Error	Effect on Fuel
1. Perilune Altitude	Causes upward bias on nominal perilune altitude, thereby increasing landing fuel.
2. Altitude late in powered descent	Defines time and altitude when altimeter data is required for safe guidance. Increased altitude error causes increased altimeter range requirement and earlier acquisition which may in turn require earlier vehicle pitch-up with resultant landing fuel penalty.
3. Range and track late in powered descent	Defines amount of terminal maneuvering required to land on pre-determined target.
4. Velocity at cut- off (Burn-out)	Defines amount of midcourse maneuvering required to place LEM on collision course with CSM.

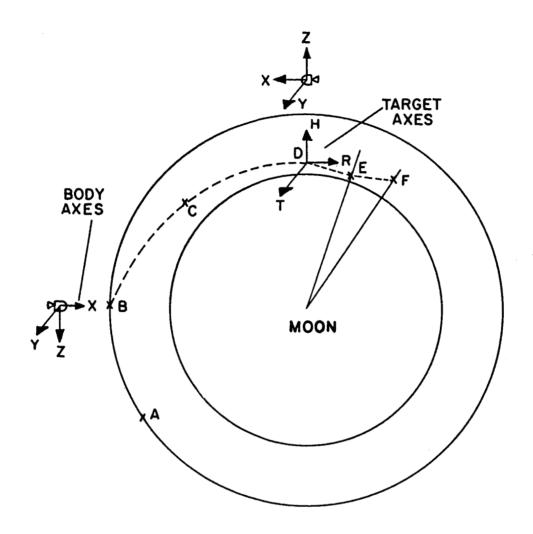
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TABLE IV

	= '	"NORMAL ASCENT"	SCENT"			
			Uncertainti	Uncertainties at Burn-Out		
Uncertainty Sources	(U)R	T(U)	н(п)	(U)Å	(U)†	ť(U)
Align X (1/2 MR)	0	-288	0	0	-1.51	0
Align Y (1/2 MR)	-86	0	430	-0.84	0	2.68
Align Z (1/2 MR)	0	-335	0	0	-2.36	0
BDX (1 ^o /Hour) Prelaunch (.25 ^o) Ascent	0 0	-2500 -47	00	00	-13.20	00
BDY (10/Hour) Prelaunch (.25°) Ascent	-750	00	3760 440	-7.33 -0.53	00	23.30 4.07
BDZ (1°/ Hour) Prelaunch (.25°) Ascent	00	-2930 446	00	0	-20.70 4.13	0 0
ACBX (0.00656 ft/sec ²)	-378	0	-78	-2.16	0	-0.71
ACBY $(0.00656 \text{ ft/sec}^2)$	0	-382	0	0	-2.21	0
ACBZ (0.00656 ft/sec ²)	-79	0	368	-0.73	0	2.04
SFEX (0.01%)	-89	0	-17	-0.57	0	-0.17
SFEY (0.01%)	0	0	0	0	0	0 (
SFEZ (0.01%)	0	0	0	0	0	0
RSS (Inertial)	853	3921	3829	7.76	25.15	23.90
RSS (Inertial)*	432	1062	1037	2.94	7.31	7.07

* Note: If total RSS prelaunch misalignment was held to 1 MR these inertial uncertainties would apply.

CONTINENTIAL



- A. ALIGNMENT PRIOR TO INJECTION (80 N.M. CIRCULAR ORBIT)
- B. INJECTION MANEUVER (373 FEET/SECOND ESSENTIALLY RADIALLY INWARD)
- C. REALIGNMENT BETWEEN INJECTION AND PERILUNE
- D. PERILUNE (50 K FEET)
- E. HOVER (LESS THAN 1000 FEET)
- F. BURN-OUT (50 K FEET)

Figure 1

VI APPENDICES

A. Analysis I GIMU - Precision Gyros - Realignment

The following represents a detailed outline of an uncertainty analysis of a LEM abort from hover. The system utilized has the following characteristics:

- 1. Gimballess inertial measurement unit (GIMU),
- 2. Precision gyros,
- 3. Realignment between injection and perilune.

The first two pages summarize the subsequent analysis. The first summary represents the case where it has been assumed that the instrument uncertainties are constant throughout the LEM mission. The second summary represents a case where instrument uncertainties are assumed to vary randomly throughout the LEM mission.

FRIAINTIES	R (U) T (U) H (U) Å (U) Å		557 989 0.68 0.56 1.90			-471 0 0 -0.65	0 -231 -0.90 0	0 0	-688 0 0 -1.14	0 -465 -1.48	1618 0 0 -0.13	0 304 -0.13 0	-1653 0 0 -4.06	0 40 -0.77 0 0.71	46 -0.07 0 -0.24	0	0 0 0 0 0	00.6	2661 628 1.91 4.35	e 2710 1172 2.03 4.40 2.82								
^	(U) H (U)		1.34 1457			0	-2.06 -540	0	0	-3.526	0	0.25	0	-1.38	0.02	0	0	+	0 4.31 1038	2 4.51 1789								
ONLI	H (U) R (U) T		1 0.50 0.55			0 -1.05	7 -0.51 0	0	01	-0.60	0 4.	5 2.14 0	0 0 -2.14	1 -0.38 0	0 0.56 0	0 0 0	0 0 0		314 2.38 5.59	687 2.43 5.62								
	UNCERTAINTES AT		1478 576 611			0 -111 0	8	0 620 0	0 -144 0	-539 0 3	0 985 0	-121 0 186	0 -576 0	-382 0 211	-7 0 30	0 0	0 0		77/8 1311 31	1670 1432 68								
	ล(บ) <u>ห</u> ์(บ)		.23			0		0		0.66	0	0.33	0	0.52		0	0		1.06	1.62								
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MCCO W	(U)Ř (0,45 0			·c	-0.19	0	0	-0.24	0	-0.13	0	-0.19	-0.04	0	0		0.41	0.61								
I - S) WI	UNCERTAINTIES AT PE (U)T (U)H (U)R		481			c	306	0	0	518	0	202	0	404	30	0	0			928								
ANALYSIS I - SUMMANY A	UNCERT/ (U)T		539			c	0	198	0	0	259	0	-202	0	0	0	0		384	703								
A	(U) R		1440			-	-142	0	0	-187	0	-404	c	-146	-78	-	, ,	,	495	1485							-	-
	UNCERTAINTY SOURCES	Orbital	Navigation	(MON I - STD)		Incritat	Align x	Alignz	BDX	BDV	. Zua	Y A C A	\$ \$ \$ \$ \$	ACDI	ACBZ	Ad 16	STEE		RSS (Inertial,	(Later) 200 r	K55 (10tal)	1			1	 		_

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	TOWN	1 010	CONTINUE							1000			13001	t ne n	EAT			
UNCERTAINTY SOURCES	(U)R		UNCERTAINTIES (U)T (U)H	AT (U)	PERILUNE R (U)†	E (U)Ĥ	(U)R	UNCERT (U) T	UNCERTAINTIES (U)T (U)H (AT.	HOVER (U) T	(U)	U R (U)	UNCERTAINTIES (U)T (U)H		AT BUR (U)Ř	BURNOUT Ř (U)Ť	(U)
Orbital Navigation																		
	1440	0 589	481	0.45	0.53	. 1.23	1478	576	611	0.50	0.55	1.34	1457	557	989	0.68	0.56	1, 90
(MODI - STD)	-											\dagger						
												*0						
Align x	0	0	0	0	0	0	0	111	0	0	1.05	0	0	471	0	0	0.65	0
Align y	142	0 2	396	0.19	0	0.51	316	0	720	0.36	0	2.93	495	0	1371	0.68	0	1.47
Align z	0	198	0	0	0	0	0	472	0	0	2.64	0	0	875	0	0	0.43	0
BDX	0	0	0	0	0	. 0	0	145	0	0	1.37	0	0	618	0	0	0.87	0
BDY	187	0 2	518	0.24	0	0.66	409	0	955	0.47	0	3.96	640	0	1822	0.93	0	2.03
BDZ	0	259	0	0	0	0	0	641	0	0	3.53	0	0	1167	0	0	1.07	0
ACBX	404	0 1	202	0.19	0	0.38	629	0	278	2, 26	0	0.53	1328	0	392	2.97	0	1, 20
ACBY	0	202	0	0	0	0	0	430	0	0	2. 20	0	0	1184	0	0	2.96	0
ACBZ	146	9 0	404	0.19	0	0.52	318	0	693	0.27	0	2.30	507	0	1516	0.81	0	3, 54
SFEX	78	0	39	0.04	0	0.07	131	0	54	0.59	0	0.13	322	0	72	0.77	0	0.29
SFEY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SFEZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RSS (Inertial)	496	384	794	0.41	0	1.06	884	923	1411	2. 42	5. 22	5.46	1667	2033	2767	3.38	3, 36	4.51
	-													. •				
RSS (Total)	1485	5 703	928	0.61	0, 53	1.62	1722	1088	1538	2. 47	5.25	5.62	2215	2108	2938	3.45	3, 41	4.89
4.																		
	1																	
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	_																	
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CONCLOSION

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	UNCERTAINTIES AT BURNOUT (U)R (U)T (U)H (U)R (U)T						0 0 0 0 0	0 0 0 0 0 0	0 -104 0 0 0.03 0	0 0 0 0 0 0	0 0 0 0 0 0	0 -356 0 0 -1,00 0	0 0 0 0 0 0		0 -223 0 0 -1,17 0	0 212 0 0 1,48 0	0 -471 0 0 -0.65 0		0 471 0 0 0 0.65 0	0 -471 0 0 -3.65 3							
A1:	UNCERTAINTIES AT HOVER (U) T (U) H (U) T (U) H						0 0 0 0 0							0 -111 0 0 -1.05			0 -111 0 0 -1.05		0 1111 0 0 1,05	0 -111 0 0 -1.05							
- 11 V	UNCERTAINTIES AT PERILUNE (U) R (U) T (U) H (U) R (U) H (U)						0 0 0 0 0												0 0 0 0 0 0	0 0 0 0							
	UNCERTAINTY SOURCES	T Alianment Drien	To Injection	1	- 22	0.0286° x inj mlm	Arithmotic Sum I	II. Realignment Prior R		- 	Z • M	•	•#	0 0286 v n r m l m	o osso o Hoy mlm	-0.01910 2 How milm	1	Arithmetic Sum II	RSS (Total)	Authmotic Sum (Total)	Attimient Sum (1962)						

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Current Curr	UNCERTAINTY SOURCES		Ĩ	NCERT	UNCERTAINTIES	AT	PERILUNE		Align-y at 1/2 mr (0. 0286°)	/2 mr (0). 0286°)		00,00	.						
No. AIN I SOURCES		(U)R	T(U)	H(O)	(U) R	(U) Ť	,	(U)R	(U) T	(U)H	A U.R.	iover (u)†	(U)		NCERT/ (U)T	AINTIES (U) H	AT BU	RNOUT		
No. ment Prior	요 :							-132	0	-27	0.04	0	-0.01	1		-43	1	٥		
No. in the citizent	-							0	0	0	0	0	0	0	0	0	٥			
No.	Ξ.							-75	0	432	. 0	0	0.26	-92	0	. 630	-0.03	0	0.37	
1	y any tanta	۲.							-63	0	- 12	-0.18	0	-0.04	- 77	0	-12	-0.22	0	0.00
H H H H H H H H H H		H.							0	0	0	0	0	0	0	0	0	0	0	0
National Property Nati		田							-33	, 0	180	-0.09	0	0.56	-40	0	272	-0.12	0	0.85
1	thmetic Sum I	+	-142	0	396	-0.13	0		-303	0	573	-0.23	0		-493	0	847	-0.28	0	1.25
1	lignment	æ							_					i .	-84	0		60		2
10 10 10 10 10 10 10 10	or To	H													0	0	0	0	0	0
11 0	ilune	王													. 70	-	00,	000		
1.		· ~												-	10-		15	0.02		-0.28
1		F													**		CI.	-0.26		0.04
0		•=													147					T
142 0 0 0 0 0 0 0 0 -436 -0.28 0 -2.83 -47 0 -1078 -0.62 0 - 142 0 396 -0.19 0 0.51 316 0 720 0.36 0 2.93 405 0 -231 -0.90 0 -142 0 396 -0.19 0 0.51 -393 0 137 -0.51 0 -2.06 -540 0 -231 -0.90 0	y Per mlm	+							-90	0		-0.28	0	-2.83	7.		-1000	0. 43		-3. 12
0 0 0 0 0 0 0 0 0 -456 -0.28 0 -2.83 -47 0 -1078 -0.62 0 0 -1078 -0.62 0 0 -1078 -0.62 0 0 -1078 -0.62 0 0 -1078 -0.62 0 0 -1078 -0.62 0 0 -1078 -0.62 0 0 -1078 -0.62 0 0 -1078 -0.62 0 0 -1078 -0.62 0 0 -1078 -0.62 0 0 -1078 -0.62 0 0 -1078 -0.62 0 0 -1078 -0.62 0 0 -1078 -0.62 0 0 -1078 -0.62 0 0 -1078 -0.62 0 0 -1078 -0.62 0 0 -1078 -0.62 0 0 0 -1078 -0.62 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	y Hov mlm	\dashv													-86	0	430	0 0		3
142 0 396 0,19 0 0.51 316 0 720 0,36 0 2.93 405 0 1371 0,68 0 142 0 306 -0.19 0 0.51 -393 0 137 -0.51 0 -2.06 -540 0 -231 -0.90 0	hmetic Sum II	1	0	0	0	0	0	0	- 90	0		-0.28	c		- 47		1070			20.5
142 0 396 0,19 0 0,51 316 0 720 0,36 0 2.93 495 0 1371 0,68 0 -142 0 396 -0,19 0 0,51 -393 0 137 -0,51 0 -2.06 -540 0 -231 -0,90 0		-															1010	-0.62		-0. 68
-142 0 396 -0.19 0 0.51 -393 0 137 -0.51 0 -2.06 -540 0 -231 -0.90 0	RSS (Total)	+	142	0	396	0.19	0		316	0		0.36	0	2.93	495		1271] !
	ic Sum (Total)	+	-142	0	396	-0.19	0		-393	0		-0.51	0	-2.06	-540		-231	-0.90	ò	0.57
		-						+												
		+																		
		+																		
		+																		
	1.	+												1						
	1	+												1						
		+																		
	_1	+																		
	!	+																		
		+																		
		+																		
		+																		
		+												-						T
		\dashv												-						T
		\dashv												+						T

0.0286° z Per mlm 0.0181° x Hov mlm

0. 0222° z Hov mlm Arithmetic Sum II

II. Realignment Prior To Perilune

Arithmetic Sum I

Arithmetic Sum (Total)

RSS (Total)

UNCERTAINTY SOURCES

I. Alignment Prior To Injection

 $0.0286^{\rm o}$ z inj mlm

									,										
								BDXat	BDX at 0.15°/hour	our									
UNCERTAINTY SOURCES		U (U)R	INCERT/ (U)T	UNCERTAINTIES AT P (U)T (U)H (U)R		AT PERILUNE (U)Ř (U)Ť	(U)	(U)R		TAINT!	ES AT (U)R	ноvеr (u) т๋	(U)	(U) R	UNCERTAINTIES (U)T (U)H	AINTIES (U) H	AT BU (U)Ř	BURNOUT Ř (U) Ť	(U)
I. Drift Between	ਸ਼																		
Alignment and	Т																		
Injection	н																		
¢	•¤														,				
0.0375 x Inj. mlm	•[-				
	÷.																,		
Arithmetic Sum I		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
II. Drift Between	R				•									0	0	0	0	0	0
Realignment and	Т													0	-137	0	0	0.05	0
Perilune	н													0	0	0	0	0	0
	ř.													0	0	0	0	0	0
	•[-													0	-464	0	0	-1.30	0
	Ĥ													0	0	0	0	c	٥
0.0375° x Per mlm								0	-145	0	0	-1.37	0						
0.0291° x Hov mlm														0	-292	0	0	-1.53	0
-0.0238° z Hov mlm														0	279	0	0		0
Arithmetic Sum II		0	0	0	0	0	0	0	-145	0	0	-1.37	0	0	-614	0	0	-0.82	0
III. Drift During	Я													0	0	0	0	0	0
Powered Descent	Ţ												,	0	1	0	0	0	0
	н													0	0	0	0	0	0
	Å													0	0	0	0	0	0
	Ţ													0	10	0	0	0.03	0
	Ĥ													0	0	0	0	0	0
Increasing x mlm								0	1	0	0	0.03	0				ŀ		
0.0133° x Hov. mlm														0	-133	0	0	-0.70	0
-0.0047° z Hov mlm														0	55	0	0	0.39	0
Arithmetic Sum III		0	0	0	0	0	0	0	1	0	0	0, 03	0	0	-67	0	0	-0.28	0
IV. Drift During																			
Powered Ascent	-													0	-7	0	0	-0.04	0
Increasing x mlm																			
Arithmetic Sum IV	\dashv	0	0	0	0	0	0	0	0	0	0	0	0	0	-7	0	0	-0.04	0
RSS - Total		0	0	0	0	0	0	0	145	0	0	1.37	0	0	618	0	0	0.87	٥
Arithmetic Sum - Total	\dashv	0	0	0	0	0	0	0	-144	0	0	-1.34	0	0	-688	0	0	-1.14	0
	\dashv																		

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	1	BDY	Y at 0.15	at 0.15°/hour					SalFigure		RIIRNOUT	
	-	RILUNE		UNCERTAINTIES	INTIES AT HOVER	٦ ٢ (ن)	(U)R	UNCER (U)T	UNCERTAINTIES (U)T (U)H	3	- 1	H(U)
UNCERTAINTY SOURCES		(U)R (U)T (U)H	_	_ \	1	1	-368	o	-57	0.12	0	0 0
٠,	1.		-172			0	0	0	0	0	0	
I. Drift Between Alignment	+		0	0		6	-120	0	820	-0.04	0	0.49
and Injection	+		-98	0	0 03	.	 	٥	-14	-0.27	0	0.04
	Ξ.		-81	0			-	0	0	0	0	0
	<u>.</u>		0	0	0		'	0	354	-0.15	0	-
0.0375° y inj mlm	E		-42	0	233 -0.12	ا	+-	0	1103	-0.34	0	1.64
	·E		-393	0	745 -0.29	0 1.00	. \	0	-17	0.03	0	0
Arithmetic Sum I.	\rightarrow						0	0	0	0	0	0
II. Drift Between	K						5	0	-629	0.03	0	-0.37
Bealismment and Perilune	H						10	-	-19	-0.35	0	0.06
Dearbare	н						-125			1	0	0
	•22						0				c	-4.13
	۰E						196		-1330	·		
	-;				1	0 -3.75						
	E		-119	0	-572 -0.37		-113	0	565	-1.10		3.51
0.0375° v per mlm							1		-1430	0 -0.83	0	-0.93
mlm you were			-119	0	-572 -0.37	0 -3.(3	+			0.01	0	0
0.0373 y inv iii							-25				0	0
	2						1			0 0	0	-0,11
III. Drift During Fowered	_						27					-0.01
Descent	1:						20					0
							0			0		0
	ద.						40		0 -272	2 0, 12	0	-0.83
	۲					6	7.2					
	•=		-27	0	-170 0.06		+		926	-0.44	4 0	1.40
							-45			C	İ	0, 43
Increasing y milli	1			6	-170 0.06	0 -0.	77 17		0			
0.0150 y hoy mlm	+	0 0 0 0 0 0	1.7				+			1	9	0.61
Arithmetic Sum III.	+		1				-	-3	0	99	200	
grawod same	7		-									
IV. Drift During 1 on cr	1		+									2
Ascent			1			٥	0	-3	0	66 -0.	08	
Increasing y mlm	1		0	0	0		_					
Arithmetic Sum IV.	-	0 0						6.40	0	1822 0.	93 0	2.03
71 Thursday	1		409	0	955 0.47		9 5	-685		-495 -1.	49 0	-
11-1-1-1		210	-539	0	3 -0.60	0	+					
RSS (Total)			_				-					
	_			1								

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	-							BDZ at	at 0.15° hour	ur									
UNCERTAINTY SOURCES		(U)R		UNCERTAINTIES (U)T (U)H	ES AT P + (U)Ř	PERILUNE Ř (U)Ť	UNE)† (U)Ĥ	(U) R		UNCERTAINTIES (U) T (U) H (AT H	HOVER (U) T	(U)	رu) R	UNCERTAINTIES (U)T (U)H	AINTIES (U) H	A 3	BURNOUT	H(U)
I. Drift Between	K							0	0	0	0	1	0	0	ŀ	0	0	0	- -
Alignment and Injection	F E	_						0	245	0	0	-0,08	0	0	232	0	0	-0.08	٥
	E	\perp						٥	0	0	0	0	0	0	0	0	0	0	0
c	요.	1						0	0	0	0	0	0	0	0	0	0	0	0
0.0375 z inj mlm	E-	\downarrow						0	0	0	0	0	0	0	-27	0	0	-0.08	0
	=	1						0	0	0	0	0	0	0	0	0	0	0	0
Arithmetic Sum I	\perp	٥	259	0		0	0	0	245	0	0	-0.08	0	0	205	0	0	-0.16	6
	æ	\perp				,								0	0	0	0	0	0
II. Drift Between	H	\perp												0	535	0	0	-0.18	٥
Realignment and	H													0 .	0	0	0	0	0
Perilune	~													0	0	0	0	0	٥
	F													0	1170	0	0	3.28	0
Ç	Ħ													0	0	0	0	0	0
0.0375 z per mlm	_[0	567	0	0	3, 45	0						
0,0238° x hov mlm														0	-239	0	0	-1.25	0
0.0291 z hov mlm	\int													0	-341	0	0	-2.39	0
Arithmetic Sum II	\int	0	0	0		0	0	0	567	0	0	3.45	0	0	1125	0	0	-0.54	0
	E I												_	0	0	0	0	0	0
III, Drift During	H						;							0	164	0	٥	-0.05	٥
Powered Descent	Ħ													0	0	0	0	0	0
	•Æ													0	0	0	0	0	0
	Ę-													0	260	0	0	0,73	0
	Η													0	0	0	0	0	٥
Increasing z mlm								0	173	0	0	0, 77	0						
0.0047 x hov mlm														0	-47	0	0	-0.25	0
0.0133 z hov mlm														0	-156	0	0	-1.10	0
위	1	0	0	0		0	0	0	173	0	0	0.77	0	0	221	0	0	-0.67	0
IV. Drift During	1																		
Powered Ascent														0	67	0	0	0, 62	0
Increasing z mlm														,					
Arithmetic Sum IV.		0	0	0	0	0	0	0	0	0	0	0	0	0	49	0	0	0.62	0
RSS (Total)		0	259	0		0	0	٥	641	. 0	0	3, 53	a	0	1167	0	0	1.07	0
Arithmetic Sum (Total)			259	0		0	0	0	985	0	0	4.14	0	0	1618	0		-0.75	0
																			į

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						AC	ACBX at 0,	00656 fe	$0,00656 \text{ feet/second}^2$	$^{\mathrm{nd}^2}$									
STORING SOURCES	-		₹	ES AT	1 111		-	1	UNCERTAINTIES AT	NTIES	AT HO	HOVER (U)	(U)	(U) R	UNCERTAINTIES (U)T (U)H	(U)H	AT BURNOUT (U) Å (U) T		(U)i
ONCENIENT		(U)R (U)T	H(0)	H (U) H	(0)	-	\dashv	l		27.	0 13	י ו	+	-468	0	-72	0.16	0	0
I. Accelerometer Bias	Я						-376				2	0	1	0	0	0	0	0	0
Bias During Injection	Ţ) i			221	0		0.13	-42	0	292	-0.01	0	0.17
	Н						-3			1	,		40 0	-40	0	9-	-0.11	0	0.03
	·я	l					-63			_	01.0			0	0	0	0	0	0
ΔH at ini = 0.19 ft/sec	•[-						0			200	20 0-		0.41	-25	0	170	-0.07	0	0.53
	÷						+			1	5		0.48	-575	0	384	-0.03	0	0.72
Arithmetic Sum I		-404 0	0 202	- 1	-0.19 0	0	38 -501		9		10.15			356	0	54	-0.12	0	0
II Accelerameter Bias	R						-							0	0	0	0	0	0
	Ţ						+							13	0	-88	0	0	-0.05
0	Н						-							755	6	113	2,13	0	-0.34
	٠ <u>۲</u>						+							0	0	0	0	0	0
Constant bias	•⊱						-							13	0	-81	0.03	0	-0.25
	•=				-		-					1			,	,	0.40	c	-0.64
A 111 marks Sum II		0	0 0		0 0		0 30	308	0	-80	2.26	0	-0.23	1136		2-	4	·	
Arithmetic Sum 11										ļ						20	91.0	١	-0.71
III. Accelerometer Bias														-378	0	8/-	01.2-		
During Powered Ascent							-							_					
							-											,	
Constant bias	\prod				0		0	0	0	0	0	0	0	-378	0	-78	-2.16	0	-0.
Arithmetic Sum III		0					+												
										010	96 6	-	0.53	1328	0	392	2.97	0	1.20
RSS (Total)		404						629	0 0	186	2, 14		0.25	183	0	304	-0.15	0	-0.63
Arithmetic Sum (Total)	\perp	-404	0 202	- 1	-0.19 0		0.38	-121		2									
	_																		
							+												
							+												
							+												
	L						+												
	L																		
	L																		
							_												
							-			,									
							+												
							+							_					
	L						-												
	-																		

CONTINUE MATERIAL

IES AT HOVER							•	ACBY at	at 0.00656 feet/second ²	feet/sec	ond ²									
1. Accelerometer Biase 2. Accelerometer Biase 2. Accelerometer Biase 2. Accelerometer Biase 3. Accelerometer Biase 3. Accelerometer Biase 4. Accelerometer Bi	UNCERTAINTY SOURCES				AINTIES	AT (RILUNE	1	9(1)	UNCERT	≝ _	AT H	I	.,		JNCERTA	VINTIES (11) H	AT BU		, H
During Injection T	ļ	ρc								- [0			0		ı		1	0
Atthreetic Sum II. Accelerometer Bias Arithmetic Sum III.		F							0	-192	0	0	0,06	0	0	-182	0	٥	0.06	0
Attitunetic Sum (Total) Attitunetic Sum (Tota	TOMOSTITE BITTING	E							0	0	0	0	0	0	0	0	0	0	0	0
Arithmetic Sum III		•æ							0	0	0	0	0	0	0	0	0	0	0	0
Hittmetic Simi I	AT at ini = 0.19 ft/sec	•[-							0	0	0	0	0	۰°0	0	20	0	0	0,06	0
H. Accelerometer Bias Powered Bias Parithmetic Sum II a constant bias Arithmetic Sum II a constant bias Arithmetic Sum III a color and an included and a color and		•#							0	0	0	0	0	0	0	0	0	0 .	.0	0
1. Accelerometer Bias 2. 2. 2. 2. 2. 2. 2. 2			0	-202	0	0	0	0	0	-192	0	0	90.0	0	0	-162	0	0	0.12	0
II. Accelerometer Blas T Constant bias		E.													0	0	0	0	0	0
During Powered H 0		F													0	-363	0	0	0.12	0
Description Rights Righ		Ħ													0	0	0	0	0	0
Arithmetic Sum IT oo o o o o o o o o o o o o o o o o o	Decrent	۰۳													0	0	0	0	0	0
H. Accelerometer Bias The constant bias Arithmetic Sum (Total)	Constant his	· E													0	-746	0	0	-2.09	0
Hithmetic Sum II	Constant stas	·H													0	0	0	0	0	0
III. Accelerometer Bias Constant bias Co	Arithmetic Sum II		•	0	0	0	0	0	0	-384	0	0	-2.20	0	0	-1109	0	0	-1.97	0
HI. Accelerometer Bias During Powered Ascent Constant bias Arithmetic Sum (Total) Arithmetic Sum												,								
Ascert Ascert Constant bias Arithmetic Sum (Total) Arithmetic Sum (T																				
Ascent Constant bias Arithmetic Sum (Total) Arithmet															0	-382	0	0	-2.21	0
Arithmetic Sum (Total) Arithm	Ascent																			
Arithmetic Sum (Total) Arithm	Constant bias																			
Arithmetic Sum (Total) Arithm	Arithmetic Sum III		0	0	0	0	0	0	0	0	0	0	0	0	0	-382	0	0	-2.21	0
Arithmetic Sum (Total) Arithm																-	,			
Arithmetic Sum (Total) 0 0-202 0 0 0 0 0 0-2.14 0 0 0-1653 0 0 0 4-1651 0 0 0 1653 0 0 0 0 1651 0 0 1651 0 0 1651	RSS (Total)		0	202	0	0	0	0	0	430	0	0	2.20	0	0	1184	0	0	2.96	0
	Arithmetic Sum (Total)		0	-202	0	0	0	0	İ	-576	0		- 2, 14	0	0	-1653	0	0	-4.06	
										į										
																				.
		L																		
								1							ļ					
																•				
																				:

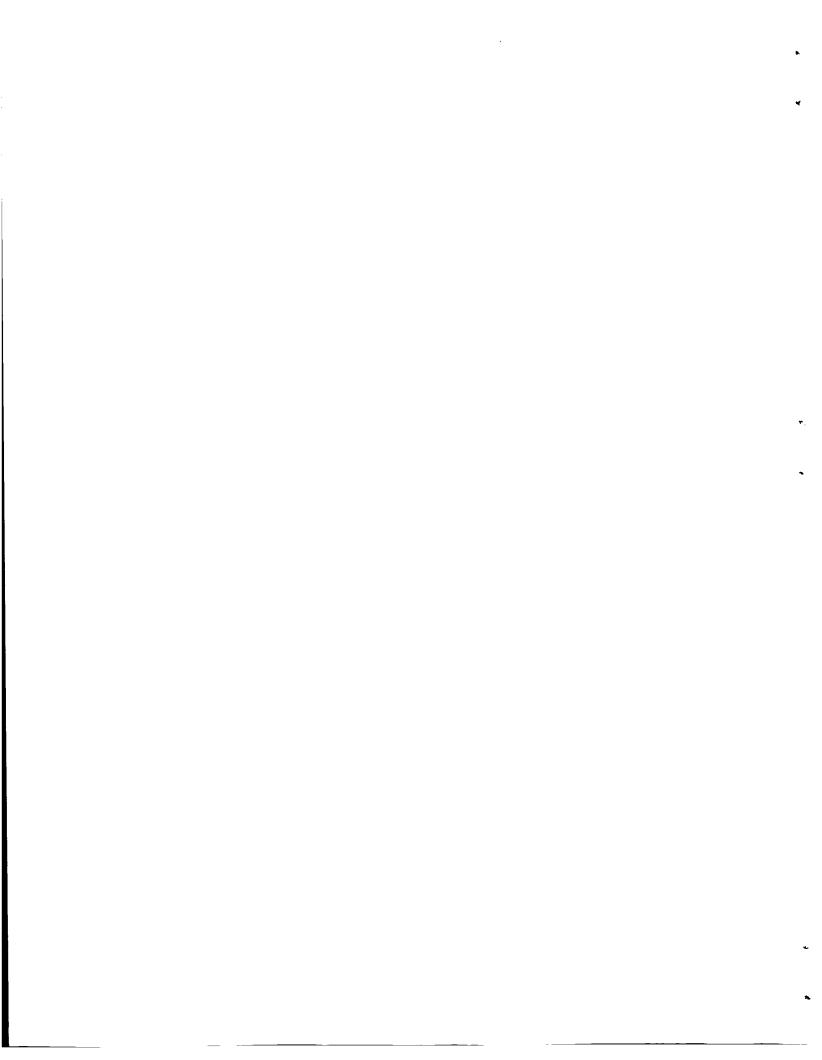


CONTINENTAL

						ĺ	ACBZ	ACBZ at 0.00656 feet/second	56 feet/	second									
		Ň	UNCERTAINTIES		1 111	1			UNCER	UNCERTAINTIES	AT.	HOVER			UNCERT	UNCERTAINTIES	AT BU	BURNOUT	• ;
UNCERTAINTY SOURCES		(U)R (I	(U)T	H(O)	(U)Ř	(u)Ť	(U)Ĥ	(U)R	T(U)	H(U)	(U)R	T(U)	H(U)	(U) R	E)	H(S)	- 1	1	H E
T Accelerometer	R							-136	0	-28	0.05	0	-0.01	-289	0	-44	0.10	٥	٥
	Ŀ							0	0	0	0	0	0	0	0	٥	0	0	0
Injection	H							-77	0	441	0	0	0.26	-94	0	643	-0.03	0	0.38
	• K							-63	0	-12	-0.18	0	-0.04	-74	0	-11	-0.21	0	0.03
ΔB at ini = 0.19 ft/sec	٠.							0	0	0	0	0	0	٥	. 0	0	0	0	0
	•:=							-33	0	183	-0.09	0	0.57	-41	0	275	-0,12	0	0.86
Arithmetic Sum I		-146	0	404	-0.19	0	0.52	-309	0	584	-0.22	0	0.78	-498	0	863	-0.26	0	1.27
II Accelerometer	æ													89-	0	-10	0.02	0	0
Rise During	F												:	0	0	0	0	0	0
Domonod Degrent	1													. 60	0	-411	0.02	0	-0.24
Lowered Descent	•0													-54	0	8-	-0.15	0	0.02
4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4	•F													0	0	0	0	0	0
Constant bras	• 12													114	0	-762	0.33	0	-2,38
Arithmetic Sum II		0	0	0	0	0	0	-73	0	-373	-0.16	0	-2.16	52	0	-1191	0.22	٥	-2.60
III. Accelerometer														_					
Bise Diming																			
Domond A cont														-79	0	368	-0.73	0	2.04
Fower of Ascelli																			
Constant bias																			
	_		c	-	c	c	0	0	0	0	0	0	0	62-	0	368	-0.73	0	2.04
Arithmetic Sum 111	1			,		,								_					
	1	146	0	404	0.19	0	0.52	318	0	693	0.27	0	2,30	507	0	1516	0.81	0	3.54
RSS (Total)	-	-146	c	404	-0.19	0	0.52	-382	0	211	-0.38	0	-1.38	3 -525	0	40	-0.77	0	0.71
Arithmetic Sum (10tal)	1		,																
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								SFEX A	SFEX AT 0.01%	.0									
UNCERTAINTY SOURCES		UNCER'	RTAI	UNCERTAINTIES (U)H (AT PERILUNE	l .	÷(O)	(U)	UNCER'	UNCERTAINTIES	AT.	HOVER (U) T	'n(U)) R (U)	UNCERTAINTIES (U)T (U)H	AINTIES (U)H	AT BU (U)Ř	RNOUT (U) T	(U)
		- 1	ı		- 1		+	1		-15	0.03	0	0	68-	0	-18	0.03		-0.01
er	2 6							0	0	0	0	0	0	0	0	0	0	0	0
Sui	E							-7	c	43	0	0	0.03	-10	0	55	0	0	0.04
Injection	-82							-13	0	۴-	-0.04	0	-0.01	-10	0	-2	-0.03	0	-0.01
ΔH at inj 0.04 ft/sec	4							0	0	0	0	0	0	0	0.	0	0	0	0
	•=							-4	0	25	-0.01	0	0.08	9-	0	35	-0.02	0	0.11
Arithmetic Sum I	+	-78 0		39	-0.04	0	0.07	96-	0	20	-0.03	0	0.10	-115	0	20	-0.02	0	0.13
	æ													83	0	13	-0.03	0	0
II. Accelerometer	E													0	0	0	0	0	0
	1 =													က	0	-22	0	0	-0.01
Fowered Descent	: -								·					197	0	30	0.54	0	-0.10
	-E-													0	0	0	0	0	0
Constant S. F.	1:													4	0	-28	0.01	0	-0.09
11 0 11	-			0	0	0	o	89	0	-20	0.59	0	-0.08	287	0	7-	0.52	0	07.9
Arithmetic Sum ii	+		,																
	+																		
III. Accelerometer	\dagger													-89	0	-17	-0.57	0	-0.17
Powered Ascent	\dagger																	:	
D + 100 + 10	T																	,	
Constant 3, F.	\dagger	c	0	0	0	0	0	0	0	0	0 .	0	0	-89	0	-17	-0.57	0	-0.17
Arithmetic Sum III	\dagger		,		,														
	\dagger	78	0	39	0.04	0	0.07	131	0	54	0.59	0	0.13	322	0	72	0.77	0	0.29
RSS (Total)	\vdash	-78		39	-0.04	0	0.07	L-	0	30	0.56	0	0.02	83	0	46	-0.07	0	-0.24
Arithmetic Sum (10tal)																			
Note:		The effects of SFEY and SFEZ	i of SI	EY and		n be nu	can be nulled to z	zero.											
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B. Analysis II IMU - Precision Gyros - Realignment

The system analyzed is identical to that utilized in Analysis I except that a gimballed inertial measurement unit (IMU) replaces the GIMU. The IMU analysis did not lend itself to the detailed breakdown of Analysis I. Therefore, only a single summary is included, representing the case where instrument uncertainties are assumed to be constant throughout the LEM mission. Comparison of this data with that of Analysis I, Summary A, indicates the effects of a gimballed vs a gimballess system.

		111	Т	Т	П	-		T	T	Τ,	#		,	7	Т	83		5.38												
	ίυ)	1,90	.	0.52		c .	2,	- 1	۲		-3.04	0.13		-0.23	- 1	53 5.03	1	56 5.												ļ [
	BURNOUT R (U) T	0.56		-1.05	-0.79	-1.83		-2.84		-4.18	٥		0	°		5,53		2.												
	AT BU (U)*	0.68		0	0	0	-2.80	٥	3,99	ار	1.33	0.11	٥	0.08		5.24		5.28												
		686		340	0	0	-542	0	970	0	-818	2	٥	96-		1424	-	1734												
	UNCERTAINTIES (U)T (U)H	557		-454	1039	-794	0	1353		-1751	0	:	0	0		2612		2671												
- 1	~	1457		0	-595	0	-944	0	911	0	92	-280	0	33		1470		2070			-				1		-	1	+	
INSTRUMENT UNCERTAINTIES CONSTANT THROUGHOUT MISSION	Н (О)	1.34	13	┼-┼-	-2.19	0	3.70	0	0,92	0	-1.56	0	0	-0.18		4.67		4.86												
опсно	HOVER (U)† (0.55		8	0 8	53		4.20	0	-2, 19	0	0	0	0		5.71		5.74												
NT THR	ES AT HO' (U)R (0,50		1 1	-0.62	l	le	0	2.09	!	0.20	-0.56	0	0.03		2,47		2.52												
CONSTA	TAINTIES (U)H (I	611 (0	101	, ,	37		341	0	183	33	0	-17		403		732												
SELLIN	UNCERTAINTIES (U) T (U)H (576 (-84	0	600	-136	921	٥	-589	0	6	, -	0	,	1275		1399												
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ENT UN	Ĥ (U)R		\parallel			+	+	+	+-	+	0 6	+	+	0	-	90	8	1 69	+											
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RY A	INTIES AT PERILUN (U)H (U)R (U)T	0.45		0	١٩١	0	- 1	9	ĺ	۲							794 0.41		928 0.											
STEINIARY) 4 1	481			396	0	0	"		7		404	39		0															
- (UNCERT (U)T	589				198	0		259	- 1	-202	0	0	0	0		384		5 703											
TAMAT COTO TE	(U)R	1440		٥	-142	0	0	-187	0	-409	0	-146	-78	0	0		496		1485	+	+	$\frac{1}{1}$	+	-	+	+	$\frac{1}{1}$	+	+	+
	ES					<u> </u>			<u> </u>					L_	L_	<u>i </u>	-									_				
	UNCERTAINTY SOURCES	Orbital Navigation	(Mod I - STD)	Inertial	Align x	Align z	BDX	BDY	BDZ	ACBX	Na O	ACBZ	SFEX	SE ES	SFEI	77.40	Des (Inemtial)	LOS ARCA LANCE	RSS (Total)											

C. Analysis III GIMU - Precision Gyros - No Realignment

The system is identical to that utilized in Analysis I except that there is no realignment between injection and perilune. In addition, analyses for the following uncertainty sources are identical to Analysis I. They will not be repeated.

ACBX

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	÷(U)		1.90			-	1	0.57		١	۹ ۱		٩	١	0	-0										1				ļ					
	(U)		95.0				-0.65	0	-0.53	-2.78	0	-1.83	0	-4.06			0	0		5.32	1	5.35													
	AT BURNOUT (U) Å (U) Ť		0	0.00			0	-0.90	0	0	-3.15	0	-0.15	0	-0.77	-0.07	0	0		3 37		3.44													
	(U)H (888			0	-231	0	0	-3355	0	304	0	40	46	0	0		2000	2266	3519													
NO	1			557			-471	0	1017	-1916	0	3868	0	1653	0	0	0	6	,		4756	4788													
MISSIC	UNCER										1			0	1	83	0			1	1123 4	1840 4													
HOUT	(U) R			1457		_	0	-540	0	0	2 -809	6	1		<u> </u> "	+	1		-	_1_		\	1_	\vdash	-	-	\mid	-	-	+	+	+	+	+	+
HROUG	(U)			1.34			0	-2.06	0	0	-11.02	0	0.25	1	1	0 02	b	6			11.30	11.38													
TANT	HOVER (U)Î			0.55			-1.05	0	2.58	4.08	.0	11 04	0	0 14	200		, 6	(ļ	12.28	12.29													
INSTRUMENT UNCERTAINTIES CONSTANT THROUGHOUT MISSION	S AT HC			0,50			_	1.5			12		0 6	c	, 6	-0.38	0.00	,	0		2.66	2.71													
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NI CIN	UNCE (U) T			576			111			62	1	-											ĺ												
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ISNI	i i i			1;23					0.01	0	0	0.66		0.38	0	0.52	0.07	0	0		1.06		1.62												
4	RILUNE			0,53				0	0	0	0	0	0	0	0	0	0	0	0		0		0,53												
VANATATOR III SIIMMARV	UNCERTAINTIES AT PERILUNE			0.45					-0.19	0	0	-0.24	0	-0-19	0	-0.19	-0.04	0	0		0 41		0,61												
CITA	IES A	10) H(0)		481 0				- 1	396 -0	0	0	518 -	0	202	0	404		0	6		200	70	928												
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14.4	UNCE	L(D)		589				0	0	198	0	0	259		-202	0																			
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) <u>}</u>		TAL	NAVIGATION	(MOD I - STD)		3	릷 ›	4 Þ	3	7				< >	×	N :	× 1	×	z		RSS (Inertial)	(Lotol) pag	1 100											
	STORING VINIATORIORS		ORBITAL	NAVI	(MOD		,	Alien X	Align A	9	Align z	BDX	וחמ ו	BDZ	ACBA	ACBI	ACBZ	SFEX	SFEY	SFEZ		RSS	2000	S. C.											
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7	ANAL	ANALYSIS III - SUMMARY B	SUMM	ARY B	H	NSTRUM	ENT UN	INSTRUMENT UNCERTAINTIES VARY RANDOMLY FROM ONE PHASE TO THE NEXT	VTTRS V	ARY RA	NDOMEN	7 FROM	ONE PI	IASE TO	THE NE	TX:			
UNCERTAINTY SOURCES		UN (U)	INCERTA (U)T	UNCERTAINTIES (U)T (U)H	AT PE (U)Ř	ERILUNE (U)†	(U)	(U)R	UNCER (U)T	UNCERTAINTIES (U) T (U) H (L	AT (HOVER (U)Î	÷(u)	U (U)R	UNCERTAINTIES (U)T (U)H	AINTIES (U) H	AT BURNOUT (U)Ř (U)Ť	RNOUT (U)†	(U)
Orbital Navigation																			
TOTAL PROPERTY.		1440	589	481	0.45	0.53	1.23	1478	576	611	0.50	0.55	1.34	1457	557	989	0.68	0.56	1.90
(MOD I - STD)																			
Inertial																			
Align x		0	0	0	0	0	0	0	111	0	0	1.05	0	0	471	0	0	0.65	0
Aligny		142	0	396	0.19	0	0.51	393	0	137	0.51	0	2.06	540	0	231	06.0	0	0.57
Align z		0	198	0	0	0	0	0	620	0	0	2.58	0	0	1017	0	0	0.53	0
BDX		0	0	0	0	0	0	0	435	0	0	4.11	0	0	1843	0	0	2.48	0
BDY	-	187	0	518	0.24	0	0.66	532	0	1878	1.15	0	11.32	664	0	4436	2,53	0	3.32
BDZ		0	259	0	0	0	0	0	1727	0	0	10.33	0	0	3389	0	0	1.87	°
ACBX		404	0	202	0.19	0	0,38	629	0	278	2.26	0	0.53	1328	0	392	2.97	0	1.20
ACBY		0	202	0	0	0	0	0	430	0	0	2.20	0	0	1134	0	0	2.96	0
ACBZ		146	0	404	0.19	0	0.52	318	0	693	0.27	0	2.30	507	0	1516	0.81	0	3.54
SFEX		78	0	39	0.04	0	0.07	131	0	54	0.59	0	0.13	322	0	72	0.77	0	0.29
SFEY	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SFEZ		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	 																	ļ	
RSS (Inertial)		496	384	794	0.41	0	1,06	972	1937	2026	2.67	11.71	11.75	1690	4188	4710	4.16	4.36	5.04
RSS (Trotal)	+	1485	703	928	0.61	0.53	1.62	1769	2021	2116	2.73	11.72	11.83	2231	4225	4812	4.22	4.40	5.39
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) H(0)	-0.01	0	0.26	-0.04	0	0.56								-2.83		-2.06	2.06	2.06	_		1				 						
		(U) T		0		0	0	0								- 0		0	0	0													
	_	- 1	0.04	0	0	-0.18	0	-0.09								-0.28		-0.51	0.51	-0.51													
6 ⁰)	···	H (U)R	-27 0	0	432	-12 -0	0	180 -0										137 -0	137 0	137 -0													
Align-y at 1/2 mr (0.0286 ^o)	UNCERTAINTIES	H(0) H			4.			1								-436		1		. 4				,									
1/2 mr	ONO	±(n) ₹	0	0	0	0	0	0								0		0		0													
ign-y at		(U)R	-132	0	-75	-63	0	-33								-90		-393	393	-393			\downarrow	1	_	ļ			<u> </u>				
Al		H(C)							0.51									0.51	0.51	0.51												٠	
	AT PERILUNE	(U)							0									0	0	0							-						
	AT P	(U)							-0.19									-0.19	0.19	-0.19													
	AINTIES	E(C)							396									396	396	396													
	UNCERTAINTIES	(U) ⊥							0									0	0	0						ļ		1					
		(U) R							-142									-142	142	-142													
}			я	Ţ	н	•¤	•[-	·H		R	Ŧ	н	·R	ŗ	Ĥ					+	\dashv	\dashv	\dagger	\dagger	†	\dagger	\dagger	T	-	\vdash			
	UNCERTAINTY SOURCES		I. Alignment Prior			0, 0286° y inj mlm										0.02860 y Per mlm	0.0286° y Hov mlm	Arithmetic Sum I	RSS (Total)	Arithmetic Sum (Total)													

PAITINATORONI	UNCERTAINTIES AT PERILUNE UNCERTAINTIES AT HOVER UNCERTAINTIES AT HOVER (U) T (U) H (U)	0 0 0 0 0 0 0 0 0	R 0 187 0 0 -0.06 0 0 111 0 0 0		5		0 0 0 0 0 0 0 0 0	0 408	0 0 0 0	982	0 196	0 433 0 0 2:22 0 0 -0.95 0	0 -260 0 0 -1.	2.58	0 198 0 0 0 0 0 0 0	0 1017 0 0 0.53	0 198 0 0 0 620 0 0 0 2.58 0	Sum (Total) 0 198 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0							
	UNCERTAINTY SOURCES	_	rior	To Injection		0, 0286° z inj mlm							0, 0286 z Per mlm	0.0181° × Hov minii	0. 02222 z Hov mlm	Arithmetic sum 1		RSS (Total)	Ariminent Dam (2007)						

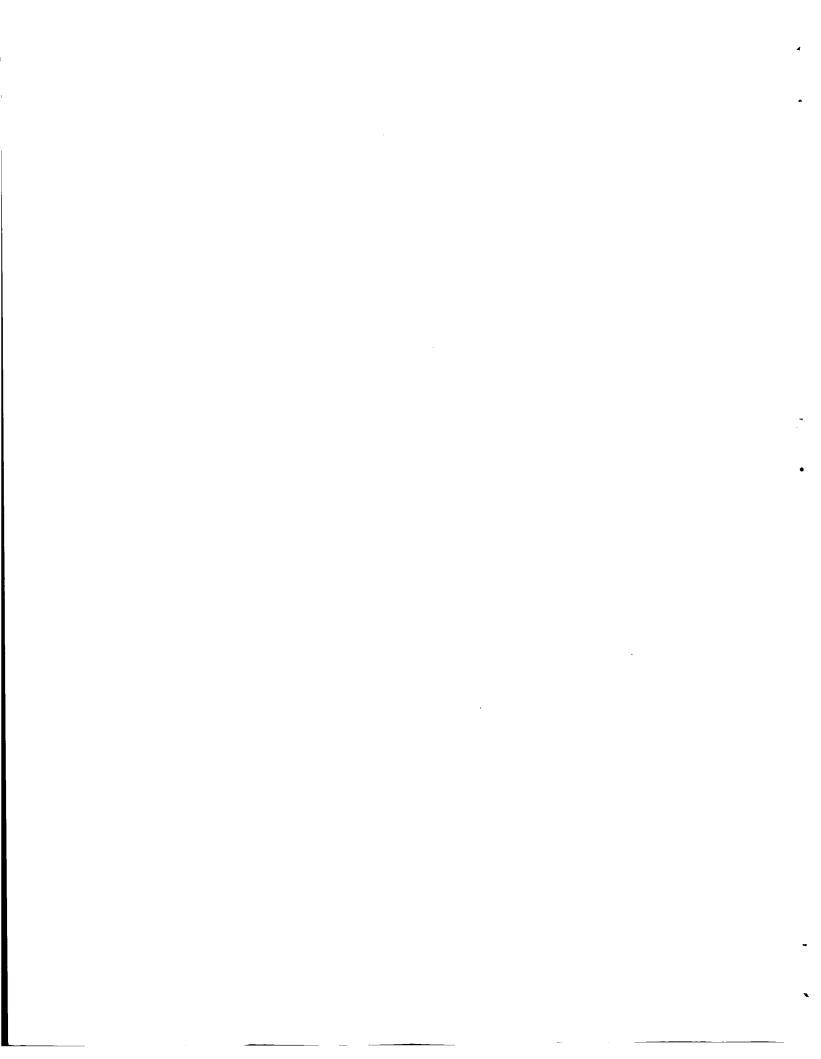


	F						BDX at	BDX at 6, 15 hour	ır								
UNCERTAINTY SOURCES		(U)R	UNCERTA (U)T	мтієs лт Р (U)н (U)Ř	NT PERIL U)Ř (U	RILUNE (U)† (U)Ĥ	i (U) R		UNCERTAINTIES (U) T (U)H (AT U) Ř	ноvеr (u) т๋	(ប)អំ	U (U)R	UNCERTAINTIES (U)H	TES AT ВІ Н (U) Å	BURNOUT R (U)T	(บ)ที่
I. Drift Between	~		-														
Alignment and	Ή																İ
Injection	Н																
	•22																
$0.0375^{0} \text{ x Inj mlm}$	•[-																
	•=																
Arithmetic Sum I		0	0	0	.0	0	0	0	0	а	a	О	a	0	О	0	O
II. Drift Between	=												0	0 0		0	0
Alignment and	Ή												0	-411 0		0.15	0
Perilune	11												0			0	0
	•¤												o	0 0		a	О
	•[-								;				0	-1392 0		-3.90	0
	·H												0			0	0
0.1125° x Per mlm							0	-435	0	0	-4,11	0					
0.0873° x Hov mlm													0	-876 0	d	-4.59	С
0.0714 ^o z Hov mlm													0			5.88	0
Arithmetic Sun II		0	0	0	0	0 0	0	-435	0	0	-4.11	0	0	-1842 0	0	-2.46	0
III. Drift During	~												0	0	0	О	0
Powered Descent	T												0	1 D	0	q	0
	Ξ												0	0	0	0	0
	•∺												0	0 0	С	а	D
	•[-												0	10 0	0	0.03	0
	•=												0	0 0	O	0	0
Increasing x mlm							0	1	0	0	0.03	0					
0.0133° x Hov mlm				and the second s									0	-133 0	d	-0.70	0
-0,0047° z Hov mlm													0	55 0	0	0, 39	0
Arithmetic Sum III		0	0	0	0	0 0	0	1	0	0	0.03	0	0	-67 0	0	-0.28	0
IV. Drift During																	
Powered Ascent													0	-7 0	0	-0.04	0
Increasing x mlm																	
Arithmetic Sum IV		0	0	0	0	0 0	0	0	0	0	О	d	0	-7 0	a	-0 04	0
RSS Total	4	0	0	0	0	0 0	0	435	0	0	4.11	0	0	1843 0	Q	2.48	0
Arithmetic Sum Total		0	0	0	0	0 0	0	-434	0	0	-4.08	9	0	-1916 0	d	-2,78	0

									-									
							BDY	Y at 0, 18	at 0, 150/hour								- 1	
UNCERTAINTY SOURCES		U)R	NCERT/ (U)T	UNCERTAINTIES (U)T (U)H		AT PERILUNE (U)Ř (U)Ť	÷(U)	(U)R	UNCER (U)T	UNCERTAINTIES (U) T (U)H (AT U)Ř	HOVER (U) T	ίυ)	(U) R	(U)T	UNCERTAINTIES (U)T (U)H	AT BURNOUT (U)R (U)T	÷ (0) ÷
1 Dwift Between	~							-172	0	-35	0.06	О	-0.01	-368	0	-57	0.12 0	9
	É							0	0	0	0	0	d	0	0	0	0 0	0
Augment and	Ę							-98	0	563	0	0	0.33	-120	0	820	-0.04 0	0, 49
Injection	· 2							-31	0	-16	-0.23	0	-0.05	96-	0	-14	-0.27 0	0 04
0	• [0	0	U	0	0	0	0	0	o	0 0	d
o. 0375 y m) mim	•=				The second second second			- 42	0	233	-0.12	0	0.72	-53	0	354	-0.15 0	1.11
A S T		.197	-	518	1.0 0.	0	0.08	-393	0	745	-0.29	0	1.00	-637	0	1103	-0.34 0	1.64
Arithmetic sum 1	r	101												-333	0	-51	0 60 0	0
II Drift Retween	í													0	0	0	0	0
II. Drut Between	• ;													273	0	-1887	0.09 0	-1.11
Alignment and Perilune	•													-375	0	-57	-1.05 0	0.18
	× •6													0	0	0	0 0	d
	1.													588	0	-3990	1.68	-12.39
	1					1			,	01.01	-		-11 25					
0.1125 ^o y per mlm								Jar		0175				-339	0	1695	-3.30 0	10.53
0.1125 ⁰ y hov mlm	1						0	-357	0	-1716	-	0	-11.25	-186	0	-4290	-2,49 0	-2.79
Arithmetic Sum II		9	0	0										-25	c	-4	0 01 0	0
A Section of the sect	H													-	٥	_	l	0
III. Dint Duting	F					Appendix and the second	-							2		,	15	-0.11
LOWer ed Descent	=					-								200		- 187		100
	•;::													202	، اد	2		
	•;-													0	٥	3	1	
	•=													40	0	-272	0.12 0	-0.83
								-27	0	-170	0.06	0	-0.77					
Increasing y mim						1								-45		226)	1.40
Arithmetic Sum III		0	0	0	0	0	0	-27	0	-170	0.00	0	-0.77	17	0	-234	-0.24 0	0.43
																	ì	1
IV. Drift During						1								-3	0	99	-0.08 0	0.01
Powered Ascent																		
Increasing v mlm																	1	
Arithmetic Sum IV		0	0	0	0	0	0	0	0	0	0	0	0	-3	0	99	-0.08 0	0.01
	1				1	:	100	1		1878	-	0	11.32	664	0	4436	2.53 0	3, 32
RSS (Total)	-	137	0	513		:	0.00	-	0		1 2		-11.02	_	٥	-3355	-3.15 0	-0.11
Arithmetic Sum ('Fotal)		-187	0	518	-0.34	0	0.66	3	0	-1141	10.1							,
						-												

	r						BDZ	at 0.	0.15 /hour										
UNCERTAINTY SOURCES		UNCER (U)R (U)T	ERTAIN)T (UNCERTAINTIES AT PERILUNE (U)T (U)H (U)R (U)T	AT PER (U)Ř (1	(U) (U)	(U)R (UNCERT (U) T	UNCERTAINTIES (U) T (U)H (AT U) Ř	ноvек (u)†	(U)	(U) R	UNCERTAINTIES (U)T (U)H		AT BU (U)Ř	BURNOUT	io)
I. Drift Between	2							O	0	a	С	0	0	0	0	0	c	0	-
it and	Н							0	245	0	0	-0, 08	0	0	232	0	0	-0.08	0
Injection	Ξ,							0	0	0	0	0	0	0	0	С	c	ے ا	٥
	<u>~</u> (0	0	0	0	0	0	0	0	0	0	0	c
0. 0375 z inj mlm								0	0	0	0	0	0	0	-27	0	0	-0.08	0
	•=					•		0	0	0	0	0	0	0	6	-	٥	c	
Arithmetic Sum I		0 259	6	0	0	0	0	0	245	0	0	-0.08		٥	205		9 0	16	
	В						-				>	3			20.4		9 6	01.0	0 (
	Н														1605	3	9 0		7
Perilune	Н													٥				+c -0-	3
	•¤						-								c	0			3
	Ť						_							0	3510	0	0	9.84	-
	•==																		,
0.1125° z per mlm							-		1701			1	,			٥	٥	0	0
0.0714° x hov mlm	-						+		1011			10.35							
0 08730 2 12	\vdash						+								-717		a	-3.75	d
mim voi s z nov mim	\dagger						+							0	-1023	0	0	-7.17	0
Arithmetic Sum II	-	0 0		0	0	0	0	0	1701	0	0	10, 35	0	0	3375	0	0	-1.62	0
III. Drift During	뀚						+							0	0	0	0	0	0
cent	H						+							0	164	0		-0.05	0
	H													0	0	0	0	0	0
*# <u></u>	·=													0	0	0	0	0	0
	- ⊢						_		:					0	260	0	0	0.73	_
•#I	•=						-							0	0	0	0	0	0
Increasing 2 mlm	-							0	173	0	0	0.77	0			,			
0.0047° x hov mlm	1													0	-47	0	0	-0.25	0
0.0133° z hov mlm	+						-							0	-156	0		-1.10	0
Arithmetic Sum III	+	0 0		0	0	0	0	0	173	0	0	0.77	0	0	221	0	0	-0.67	-
IV Drift During	-																		
Powered Ascent	+													Ú	67	0	0	0.62	0
	\dashv																		
Increasing z mlm	+																;		
Arithmetic 3um IV	\dashv	0 0		0 0	0	d	 	9	0	0	0	g	3	c	67	0	d	0 62	0
35S (Total)	+	0 250		0		0	0	0	1727	0	0	10.38	0	ç	3389	0	0	1.87	0
Arithmetic sun Totali	-	2 259	_	0		()	0	0 2	2119	0		11, 91	ς.	¢	3868	0		-1.83	٥
						I						-	The state of the s]

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D. Analysis IV IMU - Precision Gyros - No Realignment

The system analyzed is identical to that utilized in Analysis II except that there is no realignment between injection and perilune. Comparison of this data with that of Analysis III, Summary A, again indicates the effect of a gimballed vs a gimballess system.

NUCERTAINITY SOURCES UNIT (UI)H		A	ANALYSIS IV - SUMMARY	IV - SUN	TMARY A		INSTINIALENT UNCERTAINTIES CONSTANT THROUGHOUT MISSION	ENT UN	CERTA	INTIES C	ONSTA	VT THRC	UGHOU	T MISSIC	N				
UNPERTAINTIES AT PERTUNNE UNPERTAINTIES AT PERTUNMENT UNPERTAINTIES AT PERTUNNE UNPERTAINTIES AT PERTUNNE UNPERTAINTIES AT PERTUNNE UNPERTAINTIES AT PERTUNNE UNPERTAINTIES AT PERTUNNE UNPERTAINTIES AT PERTUNNE UNPERTAINTIES AT PERTUNNE UNPERTAINTIES AT PERTUNNE UNPERTAINTIES AT PERTUNNE UNPERTAINTIES AT PERTUNNE UNPERTAINTIES AT PERTUNNE UNPERTUNNE UNPERTAINTIES AT PERTUNNE UNPERTUNNE UNPERTAINTIES AT PERTUNNE UNPERTUNNE UNPERTAINTIES A								-	F0 20141	AINITIES	I	93/10	-	=	MCFRTA	NTIES	AT BUE	NOUT	
TTD) 144.0 550 481 0.40 0.83 1.23 1170 5716 611 0.50 0.55 1.34 1457 557 886 0.68 0.56 1.30 140 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	UNCERTAINTY SOURCES		UNCERT (U)T	(U)H	i	(U)†			(U)T	(U)H (5.5	1			T(U)	H (D)	(U) Ř		÷(U)
1410 549 619	Orbital																		
1,145 7,03 0.5 0. 0. 0. 0. 0. 0. 0	Navigation	1440	589	481		0.53	1.23	1478	576	1	.50	0.55		1457				3,56	1.90
National Color Nati	(MOD I - STD)												^						
National State Nati																			
1-142 0 1906 -0.101 0 0.511 -3.02 0 101 -0.062 0 -2.04 0 0 0.05 1	Inertial	c	0	0	0	0	0	0	-84	0	0	-0.90	0	0	-464	0		1.05	0
1 1 1 1 1 1 1 1 1 1	Align x	-142	0	396	-0.19	0	0.51	-302	0		0.62	0	-2.19	-595			1	0	0.52
187 0 0 0 0 0 0 0 0 0	Align z	0	198	0	0	0	0	. 0	639	0	0	2.64	0	0	1039	0		0.79	0 6
187 0 216 0 0 0 0 0 0 0 0 0	BDX	0	0	0	0	0	0	0	-357	0	0	-3.89	0	0		0		4.57	0
1,000, 1	N D	-187	0	518	-0.24	0	99.0	-397	0	- 1	2.01	0	_	-1210			1		21.0
1404 0 202 -0.19 0 0.38 -111 0 341 2.09 0 0.92 911 0 970 5.99 0 0.448 0 0 -1549 0 0 -1549 0 0 -1549 0 0 -1549 0 0 -1549 0 0 -1549 0 0 -1549 0 0 -1549 0 0 -1549 0 0 -1549 0 0 -1549 0 0 -1549 0 0 -1549 0 0 -1549 0 0 -1549 0 0 -1549 0 0 -1549 0 0 -1549 0 -1	BDZ	0	259	0	0	0	0	0	2107	0	0	11.25	0	0	3671	0		9.400	
146 0 0 0 0 0 0 0 0 0	ACBX	-404	0	202	-0.19	0	0.38	-111	0		5.09	0	0.92	911	0	970			2.46
146 0 404 -0.19 0 0.52 -235 0 183 0.20 0 -1.56 76 0 -818 1.33 0 -2.94 1-78 0 39 -0.04 0 0.07 -1.85 0 33 -0.56 0 0 0 0 0 0 0 0 1-8 0 39 -0.04 0 0.07 -1.85 0 33 -0.56 0 0 0 0 0 0 0 1-9 0 0 0 0 0 0 0 0 0	Na o o	0	-202	0	0	0	0	0	-589	0	0	-2.19	0	0	-1751	0	1	-4.18	0
1-78 0 39 -0.04 0 0.07 -1.85 0 33 -0.056 0 0 -280 0 0 0.13 0	ACBI	-146	0	404	-0.19	0	0.52	-235	0		0.20	0	-1.56	92	0	-818	1.33	0	-3.84
Total) 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	ACDZ	-78	0	39	-0.04	0	0.07	-185	0		-0.56	0	0	-280	0	2	0.11	0	0.13
Total) 1486 703 028 0,61 0.53 1.62 2379 1407 3.06 12.43 12.31 2203 4708 4005 7.24 7.85 4.98 Total) 1486 703 028 0,61 0.53 1.62 2379 1407 3.06 12.43 12.31 2203 4708 4005 7.24 7.85 4.98	CTEC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	- 1
nertial) 496 384 794 0.41 0 1.06 592 2308 1267 3.02 12.42 12.24 1653 4675 3881 7.21 7.83 4.66 [Cotal) 1485 703 028 0.61 0.53 1.62 2379 1407 3.06 12.43 12.31 2203 4708 4005 7.24 7.85 4.98 [Cotal) 1485 703 702 0.61 0.53 1.62 2379 1407 3.06 12.43 12.31 2203 4708 4005 7.24 7.85 4.98 [Cotal) 1485 703 702 0.61 0.63 1.62 1.60 0.61 0.63 1.60 0.63 1.60	SEE I	0	0	0	0	0	0	3	0		0.03	0	-0.18	33	0	-96	0,08	0	
496 384 794 0.41 0 1.06 592 2308 1267 3.02 12.42 12.24 1653 4675 3881 1.21 1.20 1.20 1.20 1.20 1.20 1.20 1.2										- 1								000	
1485 703 928 0.61 0.53 1.62 2379 1407 3.06 12.43 12.31 2203 4708 4005 7.24 7.85	RSS (Inertial)	496	384	794	0.41	0	1,06	592	2308	İ	3.02	12,42	12,24	1653	4675	3881		1.83	
1485 703 923 0.61 0.53 1.62 1532 2519 1401 5:00 12:00									000		3 0 8	19 43	12.31	2203	4708	4005	7.24	7.85	4.98
	RSS (Total)	1485	703	928	0.61	0.53	1.62	7.661	63.62			17:17] 				
	•																		
	,																		

E. Analysis V GIMU - Crude Gyros - Realignment

The system analyzed is identical to that utilized in Analysis I except that crude gyros replace the precision gyros. In addition, analyses for the following uncertainty sources are identical to Analysis I. They will not be repeated.

Align X

Align Y

Align Z

ACBX

ACBY

ACBZ

SFEX

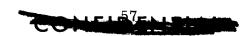
SFEY

SFEZ

			 -	,							Ţ		<u> </u>	- 1		П	27		Z		4		Т		Т	Т	_	1	 	\top	٦
	(บ)ห้		1 90			0	0.57	9	0	11,66		0,63	0	0.71	0,24	0	0		11,71	11.86											
			0.56			0.65	0	0.53	7.61	9	5.00	9	4.06	0	0	q			10.00	10.02											
	BURNC (U					•	0	j	- 1	93	1	5	1	7	7							Ì									
	AT BURNOUT (U)Ř (U)Ť		0,68			0	- 0.90	0	9	- 9.9	0	- 0.15	0	- 0.77	- 0.07	9	0		10.00	10.02											
	AINTIES (U) H		686			0	- 231	0	0	-3290	0	304	0	40	46	0	0		3313	3457											
	UNCERTAINTIES (U)T (U)H		557			471	0	1017	4584	0	10785	0	1653	0	0	0	0		11888	11901						ļ					
	œ		1457			0	540	0	0	-4571	0	183	0	525	83	0	0		4637	4861											
	<u></u>		34 1			+	_'_	-		46 -4		25		_'	02	_	_			63 4	<u> </u>			\dashv	\dashv		-	-		+	\dashv
NOI	(U)		i			0	- 2.06	0	0	-23.	0	0.	0	- 1.38	0.02	0	0		2 23,59	23.											
SIM	AT HOVER U)Ř (U)Ť		0.55			- 1.05	0	2.58	- 8.93	0	27.60	0	- 2, 14	0	0	0	0		29, 22	29. 22											
GHOUT	S AT H (U)R		0, 50			0	-0.51	0	0	-4.00	0	2, 14	0	-0.38	0.56	0	0		4.61	4.64											
Y A FHRCU	TAINTIES (U)H (611			0	137	0	0	17	0	186	0	211	30	0	0		315	687											
MMAR	UNCERTAINTIES (U)T (U)H (576			111	0	620	096	0	6567	0	576	0	0	0	0		6691	6716											
CCNS1	UNCE (U)T					ī	8		,	판		1	ŀ	81																	
YSIS V	(U)R		1478			0	- 393	9	0	-3594	Û	- 12	0	- 382	- 7	0	0		3638	3927											
ANAL,	(U)Ĥ		1. 23			0	0.51	0	0	4,40	0	0.38	0	0.52	0.07	0	0		4.48	4 65											
ANALYSIS V - SUMMARY A INSTHUMENT UNCERTAINTES CONSTANT THROUGHOUT MISSION	สเนบทธ (บ) ทั่		0.53			0	0	0	0	0	0	0	0	0	0	0	0		0	2 2 2	00.0										
TNENT	UNCERTAINTIES AT PERILUN (U)T (U)H (U)R (U)T		0.45			0	-0.19	0	0	-1.60	0	-0.19	0	-0.19	-0.04	0	0		1.63	1, 69											
INSTR	INTIES AT P (U)H (U)R		481 0			0	396 -0	0	0	3460 -1	0	202 -0		4			C		3512	0 10 10 10	!										
	TAINT (U						3			3.4		2								i											
	UNCERT (U)T		589			0	0	198	0	0	1728	0	-202	0	0	0	0		1751	1847	5										
	(U)R		1440			0	- 142	0	0	-1245	0	- 404	0	- 146	- 78		c		1327	0	1808										
																					-										
	RCES																														
	Y SOU			(0.1															(al)												
	TAINT	tal	Navigation	(MOD I - STD)	ial	×	. Y	1 2				×	: >		3 ≽	: >-	ı N	ı	RSS (Inertial)	(12) (1) (1) (1)	(1 0ta										
	UNCERTAINTY SOURCES	Orbital	Navi	(MOI	Inertial	Alion x	Align y	Align z	BDX	RDY	BDZ	ACBX	ACBY	ACB7	SEEX	SFEY	SFEZ	; ;	RSS	ŭ G	25 C										



ANAL	ANALYSIS V	- SUMM	SUMMARY B		INSTRU	TNUIN	INSTRUMENT UNCERTAINTES VARY RANDOMLY FROM ONE	SHLLNI	VARY R	- ANDOMI	LY FRO	M ONE		PHASE TO THE NEXT	E NEXT			
UNCERTAINTY SOURCES	(U)R		TAINTIES (U)H	UNCERTAINTIES AT P (U)T (U)H (U)Å	PERILUNE Ř (U)Ť	NE T (U)Ĥ	i (U)R	! !	UNCERTAINTIES AT (U)T (U)T	1 — 1	HOVER (U) T	(U)	(U) R	UNCERTAINTIES (U)T (U)H		AT BU (U)Ř	BURNOUT R (U)T	(U)
Orbital Navigation																		
(MOD I - STD)	1440	589	481	1 0.45	15 0.53	3 1.23	1478	576	611	0.50	0,55	1,34	1457	557	989	0.68	0.56	1.90
Inertial														1				
Align x	0	0	0	0	0	0	0	111	0	0	1.05	0	0	47.1	0	0	0.65	0
Align y	142	0	396	6 0.19	0 61	0.51	316	0	720	0.36	0	2.93	495	0	1371	0.68	0	1.47
Align z	0	198	0	0	0	0	0	472	0	0	2.64	0	0	875	0	0	0,43	0
BDX	0	0	0	0	0	0	0	296	0	0	9, 13	0	0	4115	0	0	5.79	0
BDY	1245	0	3460		.60 0	4,40	27.44	0	6370	3, 16	0	26.38	4272	0	12150	6.21	0	13.51
BDZ	0	1728		0	0	0	0	4276	0	0	23.57	0	0	7777	0	0	7.15	0
ACBX	404	0	202	2 0.19	0 6	0.38	629	0	278	2, 26	0	0,53	1328	0	392	2.97	0	1.20
ACBY	0	202	0	0		С	0	430	0	0	2, 20	0	0	1184	0	0	2,96	0
ACBZ	146	0	404	4 0.19	0 6	0.52	318	0	693	0.27	0	2,30	507	0	1516	0.81	0	3.54
SFEX	7.8	0	39	0.04	0 4	0.07	131	0	54	0,59	0	0, 13	322	0	72	0.77	0	0.29
SFEY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SFEZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RSS (Inertial)	1327	1751	3512	2 1.63	33 0	4.48	2855	4432	6454	3.95	25.53	26.65	4541	8933	12327	7.01	9.70	14.10
RSS (Total)	1958	3 1847	3545	5 1.69	9 0.53	3 4.65	3215	4469	6483	3,98	25.54	26.68	4769	8950 12367	12367	7.04	9.72	14, 23
	-																	
	1																	
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Unit Distribution Source Color C								BDX	at	1.00°/hour	Si									
1	UNCERTAINTY SOURCES			VCERTA (U)T		ıw				UNCERT (U) T	AINTIES (U)H (AT H				ICERTAII (U)T (I	VTIES U)H (AT BUF (U)Ř		U)÷
T T T T T T T T T T	1 Drift Retween	Я																		
H H	Alignment and Injection	Т																		
Fig. Fig.		Ή																		
1	0.2500° x Inj mlm	·¤					i													
H N	•	•[-																		
The color The		•¤					-													
Not Not																				
R R			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T T	II Drift Between	╁													0	0	0	0	0	0
Handari Handar	Realignment and Perilune	<u> </u>													0	- 913	0	0		0
Right Right <th< td=""><td></td><td>ļ</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></th<>		ļ													0	0	0	0	0	0
The color of the		•p													0	0	0	0	0	0
Harmonian Harm		• F					•								0	-3090	0	0		0
The color of the		•=													0	0	0	0	0	0
The color The	0 2500 v Dor mlm								0	-967	0	0	-9, 13	0						
The color The	0 1940 v How mlm														0	-1950	0	0	-10,20	0
The black The	-0 1590° 7 Hoy m)m														0	1863		0	13, 10	•
National Paris Par	Arithmetic Sum II		0	0	0	0	0	0	0	-967	0	0	-9.13	٥	0	-4090	0	0	- 5.47	٥
T. H. H. H. H. H. H. H. H. H. H. H. H. H.	III Duigh Duning	2													0	0	0	0	0	0
H H P	III Din During Powered Descent	F													0	7	0	0	0	0
The color of the		. 5													0	0	0	0	0	0
T T C		••													0	0	٥	0	0	0
H O		٠۴-													0	67	0	0	0.20	
The control of the co		•=													0	0	0	0	0	0
The color of the c									0	[0	0		0					ļ	
Im 0 367 0 2.60 III 0 0 0 0 7 0 0 0.20 0 0 -447 0 0 1.87 III 0 0 0 0 0 0 0 -447 0 0 1.87 IV 0 0 0 0 0 0 0 0 -447 0 0 -0.27 IV 0 0 0 0 0 0 0 0 -447 0 0 -0.27 IV 0 0 0 0 0 0 0 -447 0 0 -0.27 IV 0 <	Increasing x min														0	- 888		0	- 4.67	0
II	-0 0313° z Hov mlm														0	367	0	0	2.60	0
Ty 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Arithmetic Sum III		0	0	0	0	0		0	7	0	0	0.20	0	0		٥	٥	- 1.87	٥
IV 0	IV Drift During																			
TV 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Powered Ascent														0		0	0	- 0.27	9
Ty 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Increasing x mlm	4											į					,		,
Sum-Total 0 0 0 0 0 0 0 0 0 0 0 0 -8.93 0 0 -4584 0 0 -7.61	Arithmetic Sum IV	\downarrow	9	0	0	0	0	9	0	0	0	0		9	٩	74.	٥	٥		9
Sum-Total 0 0 0 0 0 0 0 -8.93 0 0 -4.564 0 -1.01	RSS - Total	_	0	0	0	0	0	0	0	967	0		9.13	0	٥	4115				} -
		_	0	0	0	0	0	•	0	-960	0	٥	-8.93	0	ا د	-4584				



				İ				BDY at 1,000/hour	200/hour								i		
		5	JCERT	UNCERTAINTIES	AT P	ERILUNE	1		UNCER	UNCERTAINTIES	₽.	HOVER			NCERT	UNCERTAINTIES	1A	BURNOUT	
UNCERTAINTY SOURCES		(U)R	(U)T	H(C)	(U)	(U)	(U)	(U)R	T(U)	H(U)	U)Ř	(u) †	(U)Ĥ	(U) R	(U)T	(U) H	(O)	(U) T	(บ)ห้
I. Drift Between	я							-1145	0	-233	0,40	0	-0.07	-2450	0	-380	0.80	0	0
Alignment and	F							0	0	0	0	0	0	0	0	0	0	0	0
Injection	Ξ							-653	0	3755	0	0	2.20	-800	0	5465	-0.27	0	3.26
	• K							-540	0	-107	-1.53	0	-0.33	-640	0	-93	-1.80	0	0.27
0,2500° y inj mlm	٠Ļ٠							0	0	0	0	0	0	0	0	0	0	0	0
	•¤							-282	0	1555	-0.80	0	4.87	-360	0	2368	-1.00	0	7.40
Arithmetic Sum I		-1245	0	3460	-1,60	0	4.40	-2620	0	4970	-1.93	0	6.67	-4250	0	7360	-2.27	0	10,93
II. Drift Between	н													-740	0	-113	0,20	0	0
Realignment and	H													0	0	0	0	0	0
Perilune	Н												•	909	0	-4190	0.20	0	-2.46
	٠ĸ													-832	0	-127	-2.34	0	0.40
	٠,													0	0	0	0	0	0
	Ĥ													1308	0	-8860	3,74	0	-27,60
0.2500° y per mlm								-794	0	-3820	-2,47	0	-25.00						
0.2500° y hov mlm														-756	٥	3760	-7.33	0	23.46
Arithmetic Sum II		0	0	0	0	0	0	-794	0	-3820	-2,47	0	-25.00	-414	0	-9530	-5.53	0	-6.20
III. Drift During	ж													-167	0	-27	0,07	0	0
Powered Descent	H			:										0	0	0	0	0	0
	н													180	0	-1250	0.07	0	-0.73
	•₩													133	0	20	0.40	0	-0.07
	٠,													0	0	0	0	0	0
	•¤													267	0	-1810	0.80	0	-5,68
Increasing y mlm								-180	0	-1133	0.40	0	-5.13						
0.1000 y hov mlm			ļ											-300	0	1507	-2.94	0	9.34
Arithmetic Sum III		0	0	0	0	0	0	-180	0	-1133	0,40	0	-5.13	113	0	-1560	-1.60	0	2.86
IV. Drift During																			
Powered Ascent																			
									1					-20	0	440	-0.53	0	4.07
Increasing y mlm																			
Arithmetic Sum IV		0	0	0	0	0	0	0	0	0	0	0	0	-20	0	440	-0.53	٥	4.07
RSS (Total)		1245	0	3460	1.60	0	4.40	2744	0	6370	3.16	0	26.38	4272	0	12150	6.21	0	13,51
Arithmetic Sum (Total)		-1245	0	3460	-1.60	0	4.40	-3594	0	17	-4.00	0	-23.46	-4571	0	-3290	-9.93	0	11.66

	-						BDZ at 1.	BDZ at 1.00 /hour	r.								
UNCERTAINTY SOURCES		UNCERT (U)R (U)T	UNCERTAINTIES (U)T (U)H	₽ ()	PERILUNE Ř (U)Ť	ve . (U)Ĥ	(U)R		UNCERTAINTIES (U)T (U)H (A.S.	HOVER (U)Ť	ίυ)	(U) R	UNCERTAINTIES (U)T (U)H		AT BURNOUT (U) Å (U) T	ίυ)ɨ
	2						0	0	0	0	0	О	0	0	0 0	0	9
,	E						0	1634	0	0 - 0	-0,53	0	0	1547	0 0	-0.53	d
and	, ;						0	0			0	0	0	0	0 0	0	0
TOTA DE LITTE	• 1						0	0	0	0	0	0	0	0	0 0	0	0
00036	4-€-						0	0		0	0	a	0	-180	0 0	-0.54	0
.k	•=						0	0		0	0	0	0	0	0 0	. 0	0
T control of the state of the s		0 1728	0	0	0	0	0	1634	0	0- 0). 53	0	0	1367	0 0	-1.07	0
Arithmetic sum 1	m m												0	0	0 0	0	0
II. Dritt Between Realignment and	F												0	3567	0 0	-1.20	0
Perilune	ī												0	0	0 0	0	0
	•00												0	0	0 0	0	0
	•[-												0	7800	0 0	21.88	d
	•=												0	0	0 0	0	0
c							c	3780	c	0 23	3 00	0					
0.2500 z per mlm	I						<u></u>		ĺ	ļ			0	-1592	0 0	-8.33	0
0.1390 x nov mim												i		-2275	0 0	-15.95	0
0.1940 Z nov mim						c	-	3780	c	0 23	3 00	c		7 500	0 0	-3.60	0
Arithmetic Sum II	۵	0					,							0	0 0	0	0
III. Drift During	H													1090		-0.33	0
Powered Descent	٥													0	0 0	0	0
	ς • α												0	0	0 0	0	0
	•[-												0	1730	0 0	4.87	0
	•¤												0	0	0 0	0	0
Increasing 2 min	L					:	0	1153	0	0	5. 13	0					
0.0886° z hov mlm													.0	-308	0 0	-1.67	
	-												٥	-1040	0 0	-7.33	0
Arithmetic Sum III	_	0	0	0	0	0	0	1153	0	0	5, 13	0		1472	0 0	-4.46	0
IV Drift During																	
Power Ascent	L												0	146	0	4.13	d
Increasing z mlm	L												_				
Arithmetic Sum IV	_	0 0	0	0	0	0	0	0	0	0	0	0	٥	446	0 0	4,13	٥
RSS (Total)	L	0 1728	0	С	0	0	0	4276	0	0	23. 57	0	0	7777	0		,
Arithmetic Sum (Total)				-	_	_	0	6567	0	0	27, 60	0		10785	0	-5.00	d
	-					,						i i					

F. Analysis VI GIMU - Crude Gyros - No Realignment

The system analyzed is identical to that utilized in Analysis III except that crude gyros replace the precision gyros. In addition, analyses for the following uncertainty sources are identical to Analysis III. They will not be repeated.

Align X

Align Y

Align Z

ACBX

ACBY

ACBZ

SFEX

SFEY

SFEZ

Orbital Mavigation (MOD I - STD) Align x Align z Align z Align z Align z Align z Align z Align z Align by Align z Align by Align z Align by Align z Align by Align z Align by Align z Align z Align by Align z Align by Align z Align by Align z Align by Align z A	· :	8 0 0 0 3460 8 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	UNCERTAINTIES AT PERILUNE (U)	PERILUN (U)†	ES AT PERILUNE UNCERTAINTIES AT HOVER 4 (U)Ř (U)Ť (U)Ť (U)Ř (U)Ť	(U)R	UNCER (U) T	UNCERTAINTIES (U) T (U)H ((U)R	АТ НОVЕR J)Ř (U)Ť	·i(u)	(U) R	UNCERTAINTIES (U)T (U)H		AT BURNOUT (U) T		H
retial 1 - STD) ertial			0.45														
I - STD)																	
I - STD)				0.53	1.23	1478	576	611	0.50	0.55	1.34	1457	557	686	0.68	0.56	1.90
e rtial																	T
ertial																	
											6	c	-471	0	0	-0.65	o
		$[] \mid [] \cap [] \mid []$			0 0	-303	0	137	-0.51	0	-2.06	-540	0	-231	-0.90	0	0.57
2					0	0	620	0	0	2.58	0	0	1017	0	0	-0.53	
1		\mathref{e}					-2893	0	0	-27.20	0	0	-12794	0	0	-18.54	0
					4.40	-5180	1	-7643	-8.95	0	-73.46	-5400	0	-22360	-21.00	٥	-0.74
					0	0	14127	0	0	73.60	0	0	25785	0	0	-12.20	- ا
		ļ	2 -0.19	0	0.38	-121	0	186	2.14	0	0.25	183	0	304	-0.15	0	-0.63
1		2 0			0	0	-576	0	0	-2.14	0	0	-1653	0	0	-4.06	0
	0	404	4 -0.19	0	0.52	-382	0	211	-0.38	0	1.38	4	0	40	-0.77	0	0.71
		39			0.07	2	0	30	0.56	0	0.02	83	0	46	-0.02		-0.24
SFEY		0		0	0	0	0	0	0	0	0	0	0	0	0	٠ ٠	- T
SFEZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0			>
																	- 25
RSS (Inertial) 1327	1751	1 3512	2 1.63	3 0	4.48	5210	14445	7649	9.24	78.54	73.50	5456	28854	22363	21.03	22, 58	1.33
		-		0 0	4 85	5416	14456	7673	9.25	78.54	73.51	5647	28859	22385	21.04	22, 59	2.33
RSS (Total) 1958	1847	3545	5 1.09	·	-												
						_						1					
												1					
												_					
												1					
						<u> </u>											
												+					

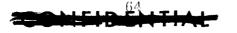
ANALYSIS VI - SIIMMABY B	- SIIMM	A R Y B				INSTRI	INSTRIMENT UNCERTAINTIES VARY BANDOMI.Y FROM ONE PHASE TO THE NEXT	NCERTA	INTIES	VARY R	ANDOMI.	Y FROM	ONE PE	TASE TO	THE N	FXT		
UNCERTAINTY SOURCES	(U)R	UNCER' R (U)T	₹	INTIES AT PI (U)H (U)R	AT PERILUNE (U)Ř (U)Ť	NE r (U)Ĥ	(U)R	UNCER (U) T	UNCERTAINTIES AT (U) T (U) H	ES AT 1	ноvея (u)†	(U)	U R (U)	NCERT	UNCERTAINTIES (U)T (U)H	=	BURNOUT	(U)
Orbital Navigation																		
	1440	589	481	0.45	0.53	1.23	1478	576	611	0.50	0.55	1.34	1457	557	989	0,68	0.56	1.90
(MOD I - STD)	\perp																	
Inertial																		
Align x	0	0	0	0	0	0	0	111	0	0	1.05	٥	0	471	0	0	0.65	0
Aligny	142	0	396	0.19	0	0.51	393	0	137	0.51	0	2.06	540	0	231	0.90	0	0.57
Align z	0	198	0	0	0	0	0	620	0	0	2, 58	0	0	1017	0	0	0.53	0
BDX	0	0	0	0	0	0	0	2900	0	0	27.40	0	0	12308	0	0	16,51	0
BDY	1245	0	3460	1.60	0	4.40	3544	0	12561	7.68	0	75.47	4430	0	29576	16.84	0	22.14
BDZ	0	1728	0	0	0	0	٥	11515	0	0	69.19	0	0	22594	0	0	12, 44	0
ACBX	404	0	202	0.19	0	0.38	629	0	278	2,26	0	0.53	1328	0	392	2.97	0	1.20
ACBY	0	202	0	0	0	0	0	430	0	0	2.20	0	0	1184	0	0	2.96	0
ACBZ	146	0	404	0.19	0	0.52	318	0	693	0.27	0	2 30	507	0	1516	0.81	0	3.54
SFEX	78	0	39	0.04	0	0.07	131	0	54	0.59	0	0.13	322	0	72	0,77	0	0.29
SFEY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	٥
SFEZ	٥	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	٩
						•												
RSS (Inertial)	1327	1751	3512	1.63	0	4. 48	3637	11899	12584	8.05	74.50	75.54	4695	25780	29618	17.16	20.90	22, 46
	-									1		Т			- 1			
RSS (Total)	1958	1847	3545	1.69	0.53	4. 65	3926	11913	12599	8.07	74.50	75.55	4916	25786	29634	17.17	20.91	22, 54
1	-																	
<u> </u>																		
	_																	
	_																	

171

r = r



							B	DX at 1.	BDX at 1.00°/hour										
UNCERTAINTY SOURCES		UN (U)	INCERTA (U)T	INTIES AT P (U)H (U)R	AT PE (U)Ř	UNCERTAINTIES AT PERILUNE (U)T (U)H (U)R	(U)Ĥ	(U)R	UNCER (U) T	UNCERTAINTIES (U) T (U)H (S AT (U)Ř	AT HOVER (U) Å (U) T	÷(U)	(U) R	UNCERTAINTIES (U)T (U)H	AINTIES (U)H	AT BU (U)Ř	AT BURNOUT (U) Å (U) T	'n(U)
I. Drift Between	22																		
	Ţ																		
1	H																		
	•æ:																		
0.2500 ^o x Inj mlm	•[-																		
	•=																		
Arithmetic Sum I		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
II. Drift Between	R													0	0	0	0	0	0
	F													0	-2750	0	0	1.00	0
Perilune	Ξ													0	0	0	0	0	0
	• 62													0	0	0	0	0	0
•														0	-9290	0	0	-26.00	0
	·=													0	0	0	0	0	0
0.7500° x Per mlm								0	-2900	0	0	-27.40	0			j			
0. 5820° x Hov mlm														0	-5840	0	0	-30.6	
-0.4760° 7 Hov. mlm														0	5580	0	٥	39.2	0
Arithmetic Sum II		0	0	0	0	0	0	0	-2900	0	0	-27.40	0	0	-12300	0	0	-16.40	0
III. Drift During	22													0	0	٥	0	0	٥
Powered Descent	Ŀ													0	7	0	0	0	0
	Ξ													0	0	0	0	0	0
	•12													0	0	0	0	0	0
	• [-													0	29	0	0	0.20	0
	•=													0	0	0	0	0	0
Increasing x mlm								0	7	0	0	0.20	0						
0.0886° x Hov mlm														0	-888	٥	0	-4.67	0
-0.0313° z Hov mlm														٥	367	0	0	2.60	0
Arithmetic Sum III		0	0	0	0	0	0	0	7	0	0	0.20	0	٥	-447	0	0	-1.87	0
IV. Drift During																			
Powered Ascent				it										٥	-47	ا		-0.27	
Increasing x mlm																			
Arithmetic Sum IV		0	0	0	0	0	0	0	0	0	0	0		0	-47	0		-0.27	
RSS - Total		0	0	0	0	0	0	0	2900	0	0	27. 40	0		12308		0	16.51	
Arithmetic Sum - Total		0	0	0	0	0	0	0	-2893	0	0	-27.20	0	0	-12794		٥	-18.54	ح



								BDY at 1	BDY at 1,000/hour	1									
UNCERTAINTY SOURCES		U) R (U)	JNCER (U)T	UNCERTAINTIES (U)T (U)H		AT PERILUNE (U)Ř (U)Ť	(U)	(U)R	UNCER (U) T	UNCERTAINTIES (U) T (U)H (AT (U	HOVER (U)	(U)	U & (U)	UNCERT	UNCERTAINTIES (U)T (U)H	S AT BURNOUT	RNOUT	, i(U)
I. Drift Between	æ							-1149	0	-233	0.40	0	-0.07	-2450			0.80	0	
Alignment and	H							0	0	0	0	0	0	0	0	0	0	0	0
Injection	Ή							-653	0	3760	0	0	2.17	-800	0	5472	-0.27	0	3,26
	ĸ							-540	0	-107	-1.53	0	-0.33	-640	0	-93	-1.80	0	0.27
0.2500° y inj mlm	·E-							0	0	0	0	0	0	0	0	0	0	0	0
	H							-280	0	1550	-0.80	0	4.90	-360	0	2360	-1.00	0	7.40
Arithmetic Sum I	\perp	-1245	0	3460	-1.60	0	4.40	-2620	0	4970	-1.93	0	6.67	-4250	0	7360	-2.27	0	10.93
II. Drift Between	ద													-2223	0	-340	09.0	0	0
Alignment and	٢													0	0	0	0	0	0
Perilune	Η													1820		-12580	09.0	0	-7.4
	٠ĸ													-2500	0	-380	-7.00	0	1.2
	•[⊢													0	0	0	0	0	0
	•H													3920	0	-26600	11.20	0	-82.90
0.7500° y per mlm								-2380	0	-11480	-7.42	0	-75.00						
0.7500° y hov mlm	_													-2260	0	11300	-22.00	0	70,50
Arithmetic Sum II		0		0	0	0	0	-2380	0	-11480	-7.42	0	-75.00	-1243	0	-28600	-16.60	0	-18.60
III. Drift During	н													-166	0	-27	0.07	0	0
Powered Descent	Ţ													0	0	0	0	0	0
	H													180	0	-1248	0.07	0 .	-0.73
-	. E													133	0	20	0.40	0	-0.07
	•E4													0	0	0	0	0	0
	Ĥ													266	0	-1810	0.80	0	-5.64
Increasing y mlm								-180	0	-1133	0.40	0	-5.13						
0.100° y hov mlm														-300	0	1505	-2.94	0	9.30
Arithmetic Sum III		0	0	0	0	0	0	-180	0	-1133	0.40	0	-5,13	113	0	-1560	-1.60	0	2.86
IV. Drift During																			
Powered Ascent	\prod																		
Increasing v mlm														-20	0	440	-0.53	0	4.07
Arithmetic Sum IV			6	c	6		,						1	8				,	
		,				,								07-		0##	50.03	5	4.01
RSS (Total)		1245	0	3460	1.60	0	4.40	3544	0	12561	7.68	0	75.47	4430	ĺ	29576 1	16.84	0	22.14
Arithmetic Sum (Total)		-1245	0	3460	-1.60	0	4.40	-5180		-7693 -	-8,95	0	-73.46	-540C	0	-22360 -	-21.00	0	-0.74
																İ			

							м 	DZ at 1.	BDZ at 1,000/hour	Į.									
INCERTAINTY SOURCES		ם	UNCERTAINTIES AT PE	INTIES	AT PER	ш			UNCER	UNCERTAINTIES	A.	HOVER			UNCERTAINTIES	AINTIES	AT B	AT BURNOUT	•
ORCENIAIN SOUNCES		(U)R	(U)T	(U)H (U)R	- 1	(U)†	٠(U)	(U)R	(U) T	H(U)	(U)R	(U) T	H(U)	(S)	T(U)	H(O)	(U)	(C) T	H(0)
I Drift Retween	ద							0	0	0	0	0	0	0	0	0	0	0	٥
Alimentation	£~							0	1634	0	0	-0.53	0	0	1547	0	0	-0.53	0
Tricotion	Ξ							0	0	0	0	0	0	0	0	0	0	0	0
nornafur	•¤							0	0	0	0	0	0	0	0	0	0	0	0
0.2500° z ini mlm	٠٢-							0	0	0	0	0	0	0	-180	0	0	-0.54	0
	•¤							0	0	0	0	0	0	0	0	0	0	0	0
Arithmetic Sum I		0	1728	0	0	0	0	0	1634	0	0	-0.53	0	0	1367	0	0	-1.07	0
II. Drift Between	R													0	0	0	0	0	0
Alignment and	٤٠													0	10700	0	0	-3,60	0
Periline	H													0	0	0	0	0	٥
	•æ													0	0	0	0	0	0
	• [-													0	23400	0	0	65.60	0
	•¤													0	0	0	0	0	0
0.75000 2 ner mlm								0	11340	0	0	69,00	0						
0 47500 v hou m]m														0	-4780	0	0	-25.00	0
0.5820° z bov mlm														0	-6820	0	0	-47.80	0
Arithmetic Sum II		0	0	0	0	0	0	0	11340	0	0	69.00	0	0	22500	0	0	-10.80	0
III Driff During	R.													0	0	0	0	0	d
	Ţ													0	1090	0	0	-0.33	0
	Œ													0	0	0	0	0	0
	٠٣													0	0	0	0	0	0
	٠Ŀ													0	1736	0	0	4.87	0
	•¤													0	0	0	0	0	0
Increasing z mlm								0	1153	0		5.13							
0.03130 x bov mlm														٥	-314	٥	0	-1.67	-
0.0886° z hov mlm														٥	-1040	0	0	-7.33	
Arithmetic Sum III		0	0	0	0	0	0	0	1153	0	0	5,13	0	٥	1472	0	0	-4.46	0
IV. Drift During																			,
Powered Ascent														٥	446	٥		4.13	-
Increasing z mlm																			
Amithmotic Gum IV							6	-	c	0	-	6	-	٥	446	0	0	4.13	a
PSS (Total)		0	1728	0	0	0			11515	0	0	69.19		0	22594	0	0	12.44	d
Arithmetic Sum (Total)		c	1728	_	0	-	0		14197	-	c	73.60		0	25785	0	0	-12.20	d
Arimitette omit (1000)		>	7100			>			4141		,				, , , , , , , , , , , , , , , , , , ,				



G. Description of Descent & Ascent Trajectory Parameters

The descent was initiated at a perilune altitude of 50,000 feet with the thrust vector oriented to $4^{\rm O}$ below the local horizontal. A constant pitch rate of 0.1138 degrees/second was maintained for 344 seconds at which point the hover condition was defined. The thrust level was maintained at 10,000 pounds and the Isp at 305 seconds. The initial thrust/mass ratio was 0.4.

The ascent was assumed to initiate at the hover point (except for the normal ascent case, Table IV, when it initiated from the lunar surface.) The initial thrust vector angle was 158.91° CW from the inertial horizontal (approx. 32° CCW from the local horizontal). A constant pitch rate of 0.1241 degrees/second was maintained for 343 seconds to cut-off. The thrust was maintained at 4000 pounds and the Isp was again assumed to be 305 seconds. The initial thrust/mass was again 0.4.



E-1473

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